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SILENT READING

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AND THEIR DISCOVERIES

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AND THEIR DISCOVERIES

By

WILLIAM & STELLA NIDA
AUTHORS OF "PIONEERS OF INVENTION"

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CHAPTER I

THE FRIAR OF OXFORD

Let us take a long, backward stride into the past, and imagine ourselves to be at Oxford as it was in the early thirteenth century. Those were very different days from ours, and that was a very different Oxford from the "City of Dreaming Spires" which we see to-day. Most of the spires were not yet built, and much of the ground now covered by stately and beautiful colleges was then open marsh and meadow. But the place was already a centre of learning, and wise men lectured in Latin to eager students, and various brotherhoods, and groups and companies of serious-minded people, were settling there, and building hostels and lecture-halls.

If we could listen to the talk of some of the students—and if we could understand it—we should not hear them speaking of cricket-matches or boat-races as the undergraduates would speak to-day; nor, if they spoke of their studies, would their conversation be very easy to follow. The first course of instruction, called the *Trivium*, consisted of grammar, rhetoric, and logic; in the second, or advanced course, the *Quadrivium*, students had to grapple with arithmetic,

geometry, astronomy, and music. These were called the "Seven Liberal Arts," and were regarded as the foundations of education; specialized branches of study were divinity, law, and medicine. All these subjects were taught in what would seem to us a very quaint and childish manner. Astronomy, in particular, was something wildly unlike the science as quite young children learn to understand it to-day. If you could hear these students of seven hundred years ago discussing the movements of the sun and stars, you would soon find that they believed the earth to be flat and motionless, and the sun and stars to revolve humbly round it for the sole benefit of mankind. Then, if you heard them speak of their fellow-students, of their teachers, or of the Franciscan and Dominican friars who had established schools at Oxford, you might catch excited whispers concerning a certain friar of St Francis, Roger Bacon by name, who was said to be in league with unseen powers, and to possess more than mortal knowledge. Friar Bacon was certainly a strange fellow. He sometimes indulged in prophecy, and declared that in the days to come carriages would move rapidly along *all by themselves*, and boats would be able to move without oars or sails, and under the water. And he maintained that to prove facts by experiments was the most important course of study a man could possibly pursue.

THE FRIAR OF OXFORD

Seven hundred years ago there was in Western Europe no such thing as serious scientific research. Men's minds were fixed upon faith, upon art, upon Christian philosophy, upon the soul and its fortunes in this world and in the hereafter; but nobody thought of pursuing *exact* knowledge *for its own sake* by means of experiment and comparison. The learning of the ancient world, of Greece and Rome, was almost beyond the reach of Western scholars. During the Dark Ages, when Europe had been overrun by barbarians, much of the wisdom of Greece was lost, some of it for ever. There was, it is true, a great Saracenic civilization in Spain, but the philosophers, the astronomers, the physicians, and mathematicians of Cordova and Granada and Seville lectured and wrote in Arabic, and the scholars of the West knew only Latin, nor had they a Latin-Arabic grammar and dictionary to help them to acquire the language of the Saracens.

All this does not mean that there were no wise and learned men in Italy and France, in England and in Central and Northern Europe. There were many. But they were seeking spiritual rather than scientific truth, and their only knowledge of one of the greatest of Greek truth-seekers, Aristotle, often came to them distorted by bad translations, and by the ignorance of the very people who tried to explain his ideas. In the eyes of these good and gifted but narrow-minded men

there was something strange and even alarming in the thought of testing and exploring the facts and the laws of Nature and of the universe. They had their own theories about the Earth and the elements, the stars and the seas, and these theories had become so stiff and hard that only a very bold man would have endeavoured to move them.

Such a man was born somewhere in England, we cannot say exactly where, some time between the years 1210 and 1215. His name was Roger Bacon, and though we know very little about his family, they and he must have been quite well off, for he was able to devote most of his life to travel and study, without having to work for his bread, and he himself has left it on record that he spent a sum equal to six or seven hundred pounds in modern money upon books and instruments, experiments and researches. As so often happens in the history of human progress in science, *two* minds were tending in the same direction almost at the same time. Roger Bacon early fell under the influence of one of the most remarkable men that have ever worn a bishop's mitre in England—Robert Grosseteste (the name means Greathead), Bishop of Lincoln. Before he was raised to the See of Lincoln, Grosseteste was Chancellor of Oxford, and there it seems that Bacon must have been one of his pupils. Though he was not such a bold and original thinker

as the younger man, Grosseteste also was far ahead of the age in which he lived. He wrote a *Compendium Scientiarum* (it must be remembered that in Latin *Scientia* means simply knowledge, *any* kind of knowledge) which was the biggest undertaking of the kind that had ever been attempted, and he saw, long before other teachers saw, the tremendous importance of Greek, Hebrew, and mathematics. This last study was spreading—though very, very slowly—over England, Italy, and France during the twelfth and thirteenth centuries. An Englishman, Adelard of Bath, had translated Euclid's geometry into Latin. But no Englishman had realized how the study of mathematics might be applied to the investigation of the mysterious and unvarying laws which govern every department and every aspect of the universe. In this sense Roger Bacon was a real and a very remarkable pioneer.

Some time between 1245 and 1250 Bacon took what appears to us to be a curious step. He became a Franciscan friar. Now, the Order of St Francis had been founded twenty years before by St Francis of Assisi, the gentle and large-hearted saint who loved everything God had made, and to whom the sun and the moon, as well as the birds and the beasts, were brothers and sisters. As Francis planned the Order, it was meant to encourage unselfishness, simplicity of life, the love of God and of one's fellow-men. A

Franciscan must be poor, humble, charitable, obedient. Learning, knowledge, science in any sense of the word, seemed far less important to the founder than the things of the heart and of the spirit. But he bade his followers seek out opportunities to kindle faith in many hearts, and that is how it befell that a band of Franciscans established themselves at Oxford, and began to labour for the good of the souls of the young men gathered together there.

Before very long the worthy friars found that they must concern themselves with the minds as well as with the souls of their flock, and they too began to lecture and teach. If this had not been so, and if the Franciscans had cared as little for learning as did their founder, it is very unlikely that Roger Bacon would have become a member of the Order of St Francis. The rule forbidding any friar to have or to hold any worldly possessions was still so strict that Roger had to obtain special permission from the Pope before he was allowed even to have pen and paper!

This mysterious friar of Oxford is, indeed, one of the most interesting and memorable figures in the history of science. His free and original mind, his thirst for positive facts, his bold and far-reaching theories, aroused suspicions and dislike in the hearts of the old-fashioned and the timid. After the death of Grosseteste in 1253, Roger Bacon's position became

one of real danger. St Bonaventura, who became head of the Franciscan Order in 1256, ordered the mysterious friar to be removed from Oxford, and kept in a sort of modified captivity at the Franciscan headquarters in Paris. Unfortunately for his material comfort, Bacon was not meek or prudent in affliction. He continued to pursue knowledge, and to mock and reproach his superiors for their ignorance and their prejudice. He even dared to attack one of the greatest philosophers among the Churchmen of the day, St Thomas Aquinas. When, in 1278, he was summoned before the head of the Order and accused of setting forth a doctrine "containing suspicious novelties," he was found guilty, and condemned to a much more severe imprisonment, which lasted for fourteen years. It is pleasant to know that he did not die in captivity, that he was allowed to return to Oxford before the end came, and that he was laid to rest in the Franciscan church of that city.

It was chiefly on account of his prophecies and his reputation as a sorcerer that Roger Bacon dwelt in the memory of the people. But here and there his influence as a philosopher endured, his works were studied, and he was remembered as the *doctor mirabilis*, the marvellous teacher—for the word 'doctor' really means 'teacher' in Latin. Let us think now of some of the discoveries made, some of the untrodden paths

explored, by this lonely friar seven hundred years ago. We cannot do better than quote the words of Dr Charles Singer:[1]

> 1. He attempted to set forth a system of natural knowledge far in advance of his time. The basis of that system was observation and experiment. He was clearly the first man in modern Europe of whom this can be said.
>
> 2. He was the first man in modern Europe to see the need for the accurate study of foreign and ancient languages. . . .
>
> 3. . . . His writings are important in the development of the following sciences:
>
> (*a*) *Optics*. His work on this subject was a textbook for the next two centuries. . . . There is trustworthy evidence that he actually used a compound system of lenses equivalent to a telescope.
>
> (*b*) *Astronomy*. . . . He spent the best part of twenty years in the construction of astronomical tables. His letter to the Pope in favour of the correction of the calendar . . . finally, at third-hand, produced the Gregorian correction.
>
> (*c*) *Geography*. He was the first geographer of the Middle Ages. . . . His arguments as to the size and sphericity of the earth were among those that influenced Columbus.
>
> (*d*) *Mechanical Science*. Suggestions by him include the automatic propulsion of vehicles and vessels. He records the working out of a plan for a flying-machine.
>
> (*e*) *Chemistry*. The chemical knowledge of his time was systematised in his tracts. His description of the com-

[1] *Mediæval Contributions to Modern Civilisation* (Harrap).

position and manufacture of gunpowder is the earliest that has reached us. . . .

(*f*) *Mathematics*. His insistence on the supreme value of mathematics as a foundation for education recalls the attitude of Plato.

We often amuse ourselves to-day with the idea of what our forefathers would think and say if they could suddenly return to the modern world, and behold some of its many mechanical wonders, motor-cars, aeroplanes, telescopes, submarines. We imagine the poor dears quite speechless and bewildered with surprise. But if Roger Bacon, the Friar of Oxford, were to return to the planet which his spirit quitted seven centuries ago he would feel no astonishment, and all he would say would probably be "*Hæc dixi*"—"I said so!"

CHAPTER II

GALILEO AND THE TELESCOPE

In ancient times people knew very little about the sun, moon, and stars. They thought the gods in some manner directed them, and when one disappeared from view in an eclipse the people were filled with fear. However, in desert countries like Egypt and Babylonia, where there are never any clouds to shut off the view, men of science gradually found out a surprising number of truths about the stars.

The desert people discovered five stars that moved about in the sky, while all the others that they could see seemed to be stationary. These five moving stars they called planets, which means 'wanderers.' They are Mercury, Venus, Mars, Jupiter, and Saturn. Our Earth is also one of these wanderers, and now we know there are still others which the ancient men could not see.

The people of those days did not know what made these planets move, nor did they know the paths they move in. We now know that the giant sun holds them from running away into space by the force of gravity, and that these children of the sun, including the Earth and a few others, revolve round him in regular paths.

They are the sun's family, and are called the solar system.

What men of those days needed most was a better eye with which to observe the stars. Without aid the human eye can see about five thousand stars only, but with a great telescope we can see hundreds of millions of them.

In the year 1608 a Dutch spectacle-maker called Lippershey found that if you look through two lenses placed at some distance apart you can see far-away objects much better, for they are magnified or made to appear larger. A single lens makes what we call a magnifying-glass. Nobody had tried two lenses together before.

Galileo, the great astronomer of Tuscany, heard of this discovery, and, as we shall see, he thought it would help him to see the stars better. So he made the best eye that had ever been turned toward the stars.

Galileo's full name was Galileo Galilei, but as he grew to manhood he preferred to be known only by his first name. The baby Galileo was born in Pisa, in 1564. The child was to become one of the greatest philosophers and inventors the world has ever known, but of course no one suspected it then. His father was a merchant of Pisa, a man of some learning who wrote on the science of music. He gave his son the best education that the time could afford.

When Galileo was a young man he attended the services at the cathedral of Pisa. He noticed one day that as the attendant lighted the lamp which was suspended from the roof, he drew it to him and let it swing back again. So it went swinging to and fro. This was before the days of pendulum clocks. While the choir sang Galileo watched the lamp with more and more interest. At first it swung wide, but the arc gradually grew less. Having no watch, he put his finger on his wrist and counted the pulse-beats. In this way he compared the vibrations with his own pulse. He soon discovered that whether the lamp swung in a wide or a narrow arc, it took the same time. This fact surprised him.

When Galileo went home he began to experiment with the idea of the swinging lamp, or pendulum, as it came to be called. Soon he had invented an instrument which marked the rate of pulse-beats. When he showed it to his teachers they were delighted. It was not long before physicians were all using the instrument to count the heart-beats of their patients.

Then the clock-makers began to use the pendulum to keep time, and it has to-day many other uses.

Galileo's father wished him to study medicine, but the young man became interested in drawing, and this led him to mathematics. Presently he became so absorbed in his new studies that his father had to yield

to the bent of his genius. He was now twenty-five—a handsome, enthusiastic young man, full of hope. His intelligence and wit charmed every one. He was appointed a teacher of mathematics in the University of Pisa in 1589. In those days all educated men studied the writings of Aristotle, the Greek scholar, and whatever Aristotle wrote they accepted. Galileo had a questioning mind, and thought every principle or stated fact should be doubted until it was tested by experiment.

Aristotle said that if two weights of the same material were dropped from the same height the heavier weight would reach the ground sooner than the lighter, and in proportion to the difference in weight. This had never been disputed until Galileo denied it, and asserted that both would fall in the same time, except with a slight difference due to the resistance of the air. Other wise men laughed at Galileo for presuming to differ from the great Aristotle. But Galileo said he could prove his statement. So one morning he took some students and teachers to the base of the famous Leaning Tower. He then climbed to the top, carrying with him a ten-pound shot and a one-pound shot. Balancing them on the edge of the tower, he let them fall together. Both struck the ground together, as he had asserted that they would.

After further study and experiment Galileo gave to

the world three great laws of falling bodies, which are studied now in schools and universities. He proved that he was right and Aristotle wrong, but he had raised a hornet's nest about his ears, for the other wise men refused to believe even their own eyes. This provoked young Galileo, and he made fun of them.

Now these men were much older than Galileo. It is neither polite nor wise to make fun of your elders. At last his enemies made it so unpleasant for him at Pisa that he was forced to resign his post, but only to get a better one at Padua. Here he worked for eighteen years, and at the age of fifty-five he was a famous lecturer and the idol of scientific men.

While on a visit to Venice in 1609, he heard about Lippershey's spy-glass, and the new invention excited in his mind the keenest interest. He procured a leaden organ-pipe and two spectacle glasses, both plain on one side, while one had its opposite side convex, and the other its second side concave. He fitted these into the organ-pipe, and this crude instrument became a telescope. It magnified things three times, or brought them to one-third of their real distance.

With this 'looking-tube' Galileo saw hosts of stars never seen before. He looked at the group of six stars which are called the Pleiades, and instead of six he saw thirty-six stars. He looked at the bright belt across the sky at night which we call the Milky Way,

and found that it consists of multitudes of stars clustered together. He turned his spy-glass on the moon, and brought it three times nearer. It was like making a voyage across an unknown sea and discovering new lands. Galileo was deeply thrilled.

Galileo carried his 'looking-tube' in triumph to Venice. It was regarded as only a toy; yet everybody wished to see an instrument that increased the power of the human eye. All the principal Venetians wished to see it, and they were much delighted. They climbed to the top of the highest tower in Venice in order to see ships, so far off that it was two hours before they could be seen without the spy-glass, steering for the harbour. The spy-glass made ships fifty miles off appear as large as if they were only fifteen miles distant. After Galileo had spent a month showing his telescope to the learned people of that wealthy city, he received an increase in his salary at Padua, and was made professor for life.

Galileo now desired to use his telescope to make still more discoveries in the heavens, but his instrument was too small. He made another and larger telescope which magnified eight times, and then another which magnified thirty times, and pointed it at the moon. His heart leaped with joy, for he saw what no human eye had ever before seen—ranges of mountains, deep hollows, and broad plains! He next turned his telescope

on the planets, and found they appeared with disks like the moon at a quarter full. He turned it on the Milky Way, and beheld innumerable tiny stars.

On the 7th of January, 1610, he turned his new telescope on the planet Jupiter, and observed three little stars near the body of the planet all in a straight line, two on the east and one on the west of Jupiter. The next time he observed them he found they had changed places and were all on the west of Jupiter. The next observation showed that they had changed again. He later discovered that instead of three there were really four of these little stars revolving round Jupiter.

"What can they be?" thought he. "They are not fixed stars, neither are they planets; so they must be moons. Jupiter, like the Earth, has a moon, but instead of one moon it has four."

More than that, Galileo observed how long it took each moon to revolve about its parent. One went round in forty-two hours, and the others took as long as seventeen days. Galileo then turned his telescope on the sun, and saw great sunspots. His friends believed him, and soon began to call him a genius.

His enemies were dismayed, but resolute. One of the professors at Padua would not even look through the wonderful instrument. Others ridiculed his discovery. Yet many of the wise and great of Italy were

admirers and companions of Galileo and praised his immense services to astronomy. Galileo wrote statements of his discoveries, and sent these with his telescope to the princes and learned men of Italy, France, and Germany. They were received with the greatest enthusiasm, and utilized at once in the hope of finding new stars.

At last Galileo discovered that the spots upon the sun move across its face. By close observation of the sunspots he found that the sun rotates like the Earth, but only once in about twenty-eight days.

Galileo had now attained his highest ambition, for he was at the head of all the scientists of Europe. Men came from far and near to study under him. But there is no height of fortune from which a man may not fall, and it is usually the proud and scornful in spirit who do fall. Galileo continued to irritate his enemies by his pride and his arrogance. He heaped scorn upon them and made fun of them. They replied that they "refused to be dragged at his chariot wheels."

The Churchmen were especially hostile. They thought Galileo was trying to undermine the authority of the Bible, and they were eager to attack him. He wrote a long letter in which he said that the Bible was not intended to teach science, but to point out the way of salvation.

Together his enemies gathered all the evidence they could find against him, and he was summoned before a court of Churchmen. Most of his judges knew little about science, so they decided that he must either go to prison or give up his new beliefs about the Earth revolving round the sun. Galileo, in dread of prison, pretended to renounce his doctrines. He did not keep his promise to be silent about them, however, and at the age of seventy he was put in prison for the rest of his life. Here he was kindly treated, and was allowed to receive visitors. Among those who came to see him was John Milton.

Then the great scholar lost his daughter, to whom he was devoted, and her death plunged him into despair. His health failed, and presently he became deaf and blind. The eyes that had seen more of the heavens than the eyes of all who had gone before him were sightless.

Galileo passed away at the age of seventy-eight, and was buried without a monument because he died a prisoner. But to-day he is honoured as a great benefactor to mankind; his discoveries are held in grateful memory; and a monument has been erected to him at Florence, where he was buried.

CHAPTER III

SIR ISAAC NEWTON SOLVES A GREAT PROBLEM

WE now have two kinds of telescopes. One kind uses lenses to gather light and bring it to a point or focus. The other kind does the same thing by using mirrors. The lens type is called a *refractor*, and the mirror type a *reflector* telescope.

The man who invented the latter kind was Sir Isaac Newton, another of the greatest men of science through all the ages. He was born at Woolsthorpe in Lincolnshire, where his family lived on a little farm.

Isaac was soon sent to the Grammar School at Grantham, but he was not very fond of his books. He was often at the bottom of his class. One day on the way to school a lad who stood just above him in class gave him a kick which caused Isaac severe pain. In a rage he challenged the other boy to fight, and they went into a churchyard near by to settle the difficulty. When all was ready, young Newton, who was smaller and weaker than the other lad, gave the bully such a good pounding that he promised to mind his own affairs in future.

Isaac felt the insults which were heaped upon him

for being a dunce, and resolved to prove that he was no fool. So he set to work in earnest, and it was not long before he was at the head of his class.

Still, he liked to make things with his hands better than he liked to study. When only a boy he made a windmill and placed it on the roof of his house. Some days the wind refused to blow, however, and then, of course, the sails would not go round. The lad determined to do without the wind and made a tread-wheel. Then he caught a mouse, and the mouse, to get some corn placed just out of reach in its cage, kept the mill going by walking on the wheel.

Next Isaac made a clock that would run by water-power. In those days there were no clocks or watches with springs to keep them going. Isaac's water-clock stood about four feet high. It had a dial-plate at the top, with figures for the hours and a hand that pointed to the right time. Every morning the lad poured in enough water to keep his clock running all day.

You may be sure that Isaac as a boy was expert in making kites, but a simple kite did not satisfy him. He made a paper lantern with a tallow candle inside. On dark nights he tied the lantern to the tail of his kite, and he and his friends watched the burning candle go bobbing about in the dark sky. The neighbours looked up and wondered what the queer light could be.

Some people said it was a comet or wandering star. This amused the boys very much.

Isaac also made sundials to give the correct time of day. A hundred years later these sundials were still to be seen at the manor-house where Isaac Newton lived as a boy. There is one at Cranbury Park, in Hampshire, to-day.

When he was fifteen Isaac's mother decided he was to be a farmer, but when she sent him to watch the cattle she found he was not to be trusted. He became interested in a brook, or in making water-wheels to run in the brook, while the cattle wandered away and enjoyed themselves in a neighbour's cornfield. He did not intend to disobey his mother, but his mind was always set on making things.

So instead of becoming a farmer Isaac was sent to Cambridge. He especially liked the study of the stars, or astronomy. In those days people knew very little about the stars. Isaac made wonderful discoveries, and by using mirrors he invented, as we have seen, a new kind of telescope which wise men praised highly.

One day, it is said, while sitting alone in his garden he saw an apple fall to the ground. "What makes heavy things always fall to the ground?" thought he. Then he began to think and study, and to ask himself questions like this, "Does the attraction of the Earth, by which this apple was pulled downward, extend as

far as the moon?" And to this he answered, "Yes!" He kept thinking about this Earth-pull that makes objects fall to the Earth until he discovered certain great natural laws. So true are they that every boy and girl who studies physics or astronomy nowadays must learn Newton's Law of Gravitation.

Kepler had discovered the laws that explain the motion of the planets, but still the great question remained: What gives the planets their motion and draws them round the sun? Newton, when only in his twenty-fourth year, solved the problem. He explained this motion so simply and clearly that no doubt remained. He said all objects on the Earth are held there by magnetism, or the force of attraction. He said the Earth was a great magnet which held all things upon it in their places and kept them from flying off into space.

Newton proved further that if the Earth attracts things close at hand, like the apple that falls, it would also attract things far off, though in a less degree. The moon, he said, goes round the Earth because of this Earth's 'pull,' and the Earth goes round the sun because of the sun's 'pull.' It is the same kind of pull that makes the moons of Jupiter go round that planet. The more distant the objects are, the less the power of attraction; and the bigger they are, the greater the attraction. This attraction Newton called *gravity.*

After Newton had proved the existence of this force by many calculations and experiments he gave to the world his great law, which is this:

"Every particle of matter in the universe attracts every other particle with a force depending upon the mass and the distance."

A body of twice the mass of another body exerts twice the pull of the other body, and a body at twice the distance exerts one-fourth the pull or force. This law of gravitation explains the motions of the moon, the planets, the sun, and the stars. It has been called the greatest discovery ever made by the human mind.

So delighted was Newton when he learned that this law had stood all the tests that he was wild with joy. "Nothing holds me," he wrote. "I will indulge my sacred fury. I will boast of the golden vessels I have stolen from the Egyptians. If you are angry, it is all the same to me. The die is cast; the book is written—to be read either now, or by posterity. I care not which. It may well wait a century for a reader, as God has waited six thousand years for an observer."

Many other discoveries were made by Isaac Newton, and the world still honours him, though he has been dead for two hundred years.

CHAPTER IV

WILLIAM HERSCHEL DISCOVERS A NEW PLANET

After the splendid discoveries of Galileo in astronomy many men began diligently to improve telescopes and to study the stars. By 1669 there were telescopes that magnified thirty-eight times. Fifty years later a telescope was made that magnified two hundred times. The largest telescopes of to-day magnify more than one thousand times.

The chief use of a telescope, as we have read, is to make far-away objects look nearer to us; to enable us to see an object miles away as if it were, perhaps, only a few yards off. Telescopes are made to do this by means of large, well-polished lenses like those used in a pair of spectacles, but much larger and more nearly perfect. These lenses collect the light rays coming from an object and bring them together to form an image or picture.

The lens type of telescope has a large lens or glass at one end of the tube, and a small lens, called the eye-piece, at the other. The use of the large lens is to act as a sort of gigantic eye. It collects a large amount of light and brings it to a focus within the tube, making

a bright image or picture, while the eyepiece magnifies this image. All great telescope-makers have been artists. Among the foremost of them was William Herschel.

Herschel was born in Germany in 1738. His father was a musician in the army. In his earliest years the lad heard a great deal of music at home. The father's salary was small, and the children often lacked food and clothing; but there was not a happier family in the place.

The father had the keenest love for music. When his hours of duty and teaching were over, he gathered his children round him, each with an instrument, for a family concert. He trained the little performers with the greatest care, for he thought that no matter what happened to them in the future, they could still earn their living by music.

William very early showed not only a taste for music, but much talent for discussion, and the father talked to the family about everything in which they were interested. Sometimes, before the evening was over, they would all go out of doors and spend an hour in studying the stars, but it was quite understood that all the sons were to be musicians.

In order to give them an early start in their profession, the father often allowed them to take part in public concerts, and their talents were so unusual that, even as children, they were given solo parts to play.

The boys attended the garrison school in Hanover, and the father continued to help them with their studies in the evenings.

As it was necessary for the children to aid in the support of the family as early as possible, William, while still a mere lad, entered the Guards as oboe-player. Still the evening concerts at home continued. William remained in the army for four years, one year of which was spent in England.

At the age of nineteen young Herschel left the Guards on account of delicate health and returned to England, with the hope of being able to earn his living there. The thought of being homeless and friendless in a foreign land did not dismay him, for he could speak English well enough to make himself understood, and could play the oboe, violin, and organ so well that he was sure of a living. So he began his new life in England with a brave heart.

For some years the young musician wandered from town to town with his music, till finally he played before Dr Miller, a noted organist of Durham, who was so delighted that he invited young Herschel to come and live with him. Herschel gladly accepted, and Dr Miller did all that could be done to advance him in the musical world until his success was certain.

Herschel was soon playing first violin in popular concerts at Durham, and had as many pupils as he could

teach. Presently he became the organist of one of the leading churches in Bath. He began to publish his compositions, and had the satisfaction of seeing them favourably received by the public.

It was in Bath that Herschel came upon a book on astronomy. He was so fascinated with it that he pored over it in every leisure moment of the day, and spent long hours of the night in studying it. He even took it to bed with him. His interest turned to astronomy, and so absorbed did he become in studying the stars that he was soon eager to scan the heavens for himself; but there was neither a telescope to which he could get access, nor one which he could buy. Consequently the musician took up the study of the mathematics necessary to design a telescope.

After Herschel had mastered the design he began the grinding of mirrors with his own unskilled hands. To grind mirrors was easier than to grind lenses. The first results were only fair, but they were encouraging. When the nights were clear the young man searched the sky with such telescopes as he had made. When they were cloudy he worked on new mirrors. Better and still better ones were made, even up to four feet in diameter, and with each one Herschel made one discovery after another in the sky. Whatever he attempted he planned very carefully, and then made a thorough job of it. This was the secret of his great success.

So interested was Herschel in the stars that he dismissed some of his music pupils to gain more time for his telescope. His brother and sister, who had come to live with him, were drawn away from their music and pressed into the work of making telescopes. The house was soon turned into a huge workshop where stands, tubes, and mirrors were made as quickly as possible. One of his sisters, Caroline by name, became almost as great an enthusiast as himself; during his lifetime she acted as his assistant, and after his death she prepared his observations on nebulæ and star-clusters for the press. She herself discovered no less than eight comets.

Herschel became so engrossed that he would not leave his workshop even for his meals, and it is said his sister could at times induce him to eat only by standing by his side and putting food into his mouth as he worked. When he was leading large orchestras at public concerts he often rushed outdoors between the acts to snatch a few glimpses of the heavens. His devotion soon brought forth telescopes far better than any that had been made, and he began to sell them to increase his income.

Wishing to study all of the stars thoroughly, Herschel made a map of the heavens in sections, so as to give careful attention to each part. He seldom went to bed on a clear night in winter or summer while the stars could be seen.

While engaged in a study of the planets he noticed the curious appearance of a white spot near to each of the poles of the planet Mars. After much study he concluded that the seasons on Mars were much like those on the Earth, and the white patches were probably snow. This belief still prevails to-day.

One night Herschel noticed a star of curious appearance, much larger than the small stars near it. He observed it carefully for two or three nights, and saw that it did not twinkle as did the others, but shone with a steady light and appeared to change its place. He therefore decided that he had found a new comet.

When Herschel announced the discovery to the world all the astronomers of Europe turned their telescopes on this interesting object to observe its motions and to calculate from them the size and shape of its path. It was soon found that the new comet did not move in a long orbit like other comets, but that it was travelling in a path more nearly round like that of the Earth and other planets. It was not long before all astronomers agreed that it was not a comet at all, but that Herschel had really discovered a new planet.

Men of science were greatly excited by this discovery. It was not only the greatest that had been made by the telescope since the splendid work of Galileo, but the greatest that had ever been made. The other planets had all been known as far back as the

memory of man, but here was a new planet moving round the sun, unknown and unseen through all the countless ages of the world.

This discovery created a new interest in astronomy. All eyes were turned with eager gaze to the starry fields of heaven, for who could tell what new wonder might be found in the far, dim fields of space?

Many honours were showered upon him who had penetrated this secret. Herschel wished to name the new planet after King George III, but other astronomers objected. Some said it would be better to give it the name of one of the old Greek gods, like the other planets. It was finally named Uranus, after the oldest of the gods.

Uranus was discovered on 13th March, 1781. Men now said that the labours of such a genius as Herschel should be given to science alone. Accordingly the King appointed him Astronomer-Royal at what now seems the very modest salary of £200 a year.

Soon after this Herschel built an immense telescope, forty feet long with a lens four feet across, which greatly aided him in his survey of the sky. On the day after it was completed he turned it upon Saturn, and saw that the planet had six moons instead of the five which were already known. A few weeks later he found the seventh moon of Saturn, the one nearest to the planet. A few years later he found that Uranus was furnished

with two moons. This discovery filled Herschel with delight, as it was one more proof to him of the wonderful harmony of the universe. But before making it known, and in order to be perfectly sure that he had not been mistaken, he made a sketch or drawing of Uranus and its moons as they should appear on a certain night. When the hour came he was greatly delighted to find that the group appeared exactly as he had pictured it.

Herschel made many other discoveries regarding the stars and the sun. Newton had proved that all the planets, together with their moons, move round the sun, held by the law of gravitation. Herschel after a deep study proved that the sun, with all his planets, is also moving through space at a marvellous speed round one of the remote stars, but just which one we do not know.

Herschel proved that all the stars which were thought to be fixed really move. They are, however, so far away that we cannot calculate their paths. If we could only view the heavens as they really are, scientists say we should see many, many systems like the sun and its planets, all moving in a wonderful plan.

In 1822, at the age of eighty-four, Herschel died. He kept his great mental powers until the last, claiming with truth that he had looked farther into space than any other eye had yet seen.

CHAPTER V

THE SILVER MOON

THE moon is the only one of all our heavenly neighbours that is near to us, but, as we shall see, even the moon is not very near. Supposing we build an imaginary railway to the moon. How long would it take an express train, going at forty miles an hour, to reach that globe? If it went a thousand miles in a day and a night the journey would require two hundred and forty days, or about eight months of travelling night and day. If we started when school opens in September we should not reach the moon until April in the following spring. When we arrived we should be almost a year older than when we started.

Because the moon is so far away it looks no bigger than a football; but it is really very large. You do not think a globe small if it has a diameter of two thousand miles. Think of the distance from London to Port Said as the diameter of an immense ball, and you have a globe about the size of the moon.

With the aid of the great Lick telescope the moon can be magnified a thousand times; that is, it looks as if it were a thousand times nearer than it really is, or as we should see it if it were only two hundred and forty

miles away. It would appear as if it were in Paris and we were in London. In the larger Mount Wilson telescope the moon is brought to within fifty miles of the Earth. Through this telescope you could see a large city on the moon, if one were there, or even a very large building like St Peter's at Rome. However, there are no such cities or buildings on the moon. We could even detect a big airship as a moving speck against the surface of the moon, but we find no signs of man's work there. Astronomers have looked for them thousands of times.

When we look at the moon through a telescope we can see that it has no signs of water. We could see a large river valley if any were there. No deep cañons can be discovered in the mountain-sides; neither are there clouds, so there can be no water.

Astronomers tell us that there is no atmosphere surrounding the moon. Now if there is neither water nor air, what can we say about people and animals, about trees and plants, on the moon? It would be hard to imagine an animal that could live without air and water. Because there is neither air nor water on the moon, it can have no weather. It is so cold on the moon at night that no man could possibly exist there. It is thought to be a frozen ball because it has no coat of atmosphere to hold the heat that the sun gives it.

You know that our atmosphere serves as a blanket

to the Earth. This air blanket prevents the escape of heat from the Earth and also shields us from too much heat from the sun. Since the moon has no atmosphere at all, you can imagine how very hot it must be underneath the sun's direct rays, for they fall five times more fiercely on the moon than they do on the Earth. On the other hand, how piercingly cold it must be during the long night there. The moon cools down to 250 degrees below zero. This is cold enough to freeze air.

One great astronomer, Professor Pickering, thinks that he can see signs of some sort of feeble life or movement on the moon. He speaks of a very thin atmosphere and of occasional light falls of snow. But other astronomers do not agree. They all assert that neither air nor water can be found.

One strange thing about the moon is that it always keeps the same face or side toward the Earth. We have never seen the other side of the moon, so we do not know what that side looks like. The moon turns only once on its axis every time it goes round the Earth; that is, once about every twenty-eight days.

For fourteen of our days there is continuous night on the moon, and the temperature must sink very low toward the absolute cold of space. Then will come full daylight for fourteen days, when the sun's rays blaze down with no atmosphere or clouds to absorb the heat or light. Astronomers are not agreed as to

how warm the days on the moon may be, whether the temperature is always below freezing, or whether during the long days it goes above the boiling-point of water.

There is an enormous number of craters, or huge pits, on the moon's surface. Some think these craters were made by very large meteors falling into the moon. Other astronomers think these craters are the remains of gigantic bubbles of gas which were raised on the moon's skin by the heat of the sun. Still others think they are craters of dead volcanoes. Our craters on the Earth are generally deep cups; whereas those on the moon are broad, shallow saucers. Clavius, the largest of them, is one hundred and twenty-three miles across. Yet the rim of this crater is not a mile high.

The mountains on the moon rise to a great height and are very rugged. They are like fountains of lava, and rise in places more than five miles high. Our Earth mountains are continually being worn down by frost, ice, and water, but as these elements of the atmosphere are not found on the moon its mountains are 'everlasting hills.'

So far as we can see, not the slightest change ever takes place on the moon. A stone lying on the Earth's surface is continually attacked by the weather, and in the course of years it is gradually worn away by the wind and rain. But there is no weather on the moon,

and a stone lying on its surface might rest there undisturbed for unknown ages. The surface of that body is heated when the sun shines upon it, and it cools when the sun has set. Except for these changes in temperature, there is nothing going on over the whole round surface so far as we can see.

The soft silvery moonlight which we all enjoy so much is the light which the moon catches from the sun and reflects to us on Earth. The moon itself is cold and solid, and sends out no light of its own. Like a great, round, rough, silver mirror it catches what sunlight it can and sends it to the Earth. If you will look closely when the moon is new you will see not only the bright crescent, but also the faint outline of the whole sphere. The crescent is the part that is receiving the sun's rays, while the dim part is seen only because the Earth is shining like a moon upon it. You must remember that to the moon our Earth is also a moon, and because the Earth is so much larger the Earthshine is almost fourteen times as bright as moonshine.

It would be pleasant to think of boys and girls on the moon, and grown-ups, too, all enjoying our Earthshine, but we know that there can be no people there, nor flowers, trees, or life of any kind.

Let us imagine we live on the moon. How will the Earth look to us? It will then be our moon, and it will be a many times bigger moon. But it will not rise and

set, for the moon always keeps the same face or side toward the Earth. We might live on the other side of the moon and never be allowed to see the Earth at all. But if we see the Earth it will behave just as our moon does, except that it will always be seen about the same place in the sky. Sometimes the Earth will be dark; then new Earth, half Earth, and full Earth. If it looks about fourteen times as large as our moon, then when night comes on the moon the Earthshine will surely be very bright, especially when the Earth is full.

If we were to imagine ourselves living on the moon we should have to think of doing without all the things that we enjoy from air, water, and snow. There would be no storms or winds, no clouds or anything flying overhead. There could be no sounds, because sounds are air-waves. We could not talk with the voice; therefore we should need some sign language.

While on the moon we should see no shooting stars, since these are meteors passing through atmosphere, and are being burned up by it. From the moon the sky would be black; not the lovely blue which is due to the Earth's atmosphere. Scientists have proved that light consists of three colours—red, yellow, and blue. There are three parts of the yellow, five of the red, and eight of the blue; and these three colours make black. The Earth's atmosphere sifts out the other colours and leaves us a blue sky, but the moon, having

no atmosphere, has a sky as black as coal. However, the stars would shine all night and all day in the black sky of the moon.

We should be able to see from the moon the gigantic flames of burning gas streaming out from the sun all the time, which only astronomers have been fortunate enough to observe when there has been an eclipse.

When the moon comes exactly between the sun and the Earth the moon shuts off the light from the sun and leaves us in darkness. This is called an eclipse of the sun. This darkness lasts only a few minutes, as both the Earth and the moon are moving very rapidly, and presently the moon is out of the way and the sunshine returns to us.

There is also an eclipse of the moon. This is caused by the Earth's getting between the moon and the sun, so as to cut off the sunshine upon the moon, for you remember we see the moon only when the sun is shining upon it.

Astronomers often go on long expeditions with their telescopes to observe an eclipse, for it may not be seen at all places on the Earth. The scientists must work rapidly to make observations in the three or four minutes during which the eclipse lasts. Sometimes clouds shut out their view of the sky. This is a keen disappointment to the astronomers who have their telescopes ready to learn something new during these unusual times.

When the Earth turns round we do not fall off because the Earth-pull, called *gravity*, holds us to the ground. Since the moon is so much smaller, the force of gravity there is only one-sixth as much as it is on the Earth. On the moon you would weigh only one-sixth as much as you do here. You could run six times as fast, jump six times as high, or hit a ball six times as far. How would you like to bowl in a cricket-match on the moon?

Though a dead world, the moon is a wonderful companion of the Earth, and it largely controls our ocean tides. Its changing form is interesting. In olden times people believed that the moon exercised a powerful influence not only upon crops and harvests, but upon the minds of men.

CHAPTER VI

THE SUN

Our sun is a huge fiery ball, one hundred times as great in diameter as the Earth, and more than a million times as large. But, strange as it may seem, the sun is only a star like the other stars that we see in the sky at night. Stranger still, we find that our sun is only a medium-sized star. It is not as large as the Pole Star, and not nearly as large as some of the others. Betelgeux, in the constellation of Orion, is reckoned to be four hundred times larger than the sun. The sun, compared with other stars, looks large to us because we are nestled close to it. If the sun were gradually to move farther from the Earth until it was as far away as the other stars, its light would grow so dim that its glory would be gone.

We have seen that an express train would require eight months to make the run to the moon. How long do you think it would take us to go to the sun, which is nearly four hundred times as far from us as the moon? It would take an express train two hundred and fifty-five years for such a journey.

If we were to make this journey we should find an express train entirely too slow; not only should we die

before reaching the sun, but our great-grandchildren would not survive the journey. We shall have to find some faster way of travel, for even an aeroplane would take too long. We know that a cannon-ball moves at a tremendous rate—twenty or thirty miles a minute. If it could maintain that speed it would move thirty thousand miles in a day, and could reach the moon in eight full days. But it would take our cannon-ball seven years or more to reach the sun.

Let us think of the distance to the sun in another way. We know that the sun is very hot. If you had an arm ninety-three million miles long and sat in your home with your finger on the sun, you would be burned, but how long would it be before you would know that you were burned? Pain travels five feet in one-twentieth of a second. If you put your finger in the fire you are burned before you feel the pain. It is felt one-hundredth of a second after you are burned. Now, if you should stick your finger in the sun with your long arm, you would wait a year and not feel the pain. You would wait ten years and yet not feel it. It would take the pain one hundred and fifty years to arrive from the burn received from the sun.

Light comes from the sun to us in a few minutes, for light travels 186,400 miles a second. So it shoots through to us in about eight and a quarter minutes. When we look at the sun we see it, not in the place

where it actually is in the sky, but in the place where it was eight minutes before.

The sun's orb sends out light and gives out heat in every direction possible. Only the least fraction of the sun's heat comes to the Earth, but enough reaches here to keep every living thing on Earth alive. It supports the plants and the trees and all the men and animals. It raises clouds and makes possible all the work that is done. What the sun does for the Earth seems like magic, since we are so very far away from it. Because the sun is tremendously hot it can give us heat at this great distance. If the rays of the sun were shut off from our atmosphere for a few days the air would soon be chilled and the Earth frozen.

We know that the sun is about ninety-three million miles away. If it were only half as far away we could set paper on fire by putting it out in the sunshine. We think the sun's heat is very great on the Earth on a summer day, but it is forty-six thousand times greater at the sun's surface. There it would melt a layer of ice forty-one feet thick in one minute.

We cannot look long at the sun in a clear sky, for it is so brilliant that it hurts our eyes. It is better to look at it through smoked glass, or when the atmosphere is very hazy. If we should look at it through a telescope we should find that it is covered with spots. There are dark spots to be seen upon it, some of which

we may see with the naked eye in cloudy or foggy weather.

Some of these sunspots are so large that they seem to be great holes in the sun, so large that our world could drop into one of them and have a thousand miles to spare round it. Some astronomers say the spots are not holes but vast whirlpools. One remarkable thing about these spots is the fact that the sun has an especially bad attack of them about every eleven years. It is by watching the sunspots that we can tell how long it takes the sun to turn on its axis. It revolves once in about twenty-six days.

We know that there are tremendous explosions on the sun, for through the telescope when the moon is between us and the sun we can see the flames shoot out from twenty-five thousand to three hundred thousand miles.

The sun's surface seems to be a boiling ocean of white-hot metal vapours. This ocean of white-hot gas is constantly driven by great storms. Some terrible energy is streaming out from the sun and blowing its outer layers into gigantic hurricanes.

By using the spectroscope we learn what elements there are in the sun—such elements as iron, copper, zinc, hydrogen, and helium. These are also found on the Earth, but not in the same form. The sun's heat is so intense that they are all turned to gases. There

appear to be other elements on the sun that we have not yet found on the Earth. With our fine instruments one element was found on the sun thirty years before we found it here.

Suppose we wanted to make two balls—one to show the size of the sun and the other the Earth. We should make the globe to represent the sun twenty-six feet in diameter, and the ball that stands for the Earth about the size of a tennis-ball. Jules Verne wrote of a journey round the world in eighty days, but it would have taken his travellers nearly twenty-four years to go round the sun at the same rate. If the Earth were to swell to the size of the sun and men were to grow in the same proportion, a man would be six hundred and twenty-five feet tall. He could stand by St Paul's Cathedral and would tower two hundred and sixty feet above the cross on its summit.

One of the things concerning the sun that puzzles us a great deal is how its heat is maintained. There are tens of thousands of acres of coal-bearing land in the world. But if we should bring all the coal together in one huge fire, how long do you think it would give out the heat of the sun? It would supply the heat of the sun one ten-thousandth part of a second. We really do not know just how the sun's heat is produced. Some think that it is from radium on the sun. Some say that it is from the breaking down of atoms.

The time may come when the sun will use up all its fuel and will become frozen and lifeless like some of the planets that move round it. But this could not happen for so many million years that we need not feel alarmed.

The Earth is pulling everything toward it by gravitation, as we know. Now the sun pulls very much harder than the Earth, twenty-seven times as hard. For this reason, everything on the sun weighs twenty-seven times as much as it would here. A man of ordinary size would weigh more than two tons there. He would be so heavy that he could not walk.

The sun pulls the Earth as a magnet pulls a piece of iron. Our Earth moves round in a circle or path, called its *orbit*, and the sun never lets it get away. There are seven other planets that are held captive by the sun and made to travel round it in regular paths. This seems like magic. Then when we think that our sun is only one of millions of stars, and that they all may have planets moving about them, we can appreciate how wonderful is the great universe.

CHAPTER VII

THE SUN'S FAMILY

THE Earth and several other globes that revolve round the sun are called *planets.* Planets are not stars, because they do not shine by their own light. We can see the other planets only because the sun is shining on them, and they reflect the light to us. On an excursion to the sun we should pass only Venus and Mercury. They are the only two planets that are closer to the sun than the Earth.

The sun, we might say, has a family of eight children that get all their heat and light from him. Each moves round the parent in a great circle. Some are close to the father sun, and some are far away. One of these eight children is our own Earth.

So let us say our Earth has seven sisters. This family of eight planets forms what is called the *solar system.* The sun is the centre and is chief of the system, with the Earth and other planets moving round it. The children of the sun, or the planets, are called Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The same sun warms them all, and the same stars shine upon them all; but they differ much from one another, and each one is very interesting.

This family of eight planets is moving, each in its own path, millions and millions of miles away from the sun, so that you might think they were going off into space to join some other sun; but they keep in their paths year after year and come back to their places, and have done so no one knows how long. Astronomers can calculate just where each one will be a year or a hundred years from now, or where each one of them was a hundred years ago. Now close your eyes and see if you can imagine how the sun and his family look. Think of a bright sun and eight little faint specks moving round it, all in the same direction.

MERCURY, A FIERY WORLD

Mercury is the baby of the great sun's family and is not much larger than our moon. We sometimes see Mercury as a bright star near the western horizon just after sunset. It is then an evening star. Some days later we see the same planet as a morning star before sunrise in the eastern sky. It swings round the sun, and we see it now on one side and then on the other, but we cannot see it except when the sun is hidden, for his glare is too bright. That is why Mercury can be seen only just before sunrise or after sunset. It follows or precedes the sun across our sky every day.

Mercury is the planet nearest to the sun. We should not call it near, for the distance is about thirty-six

million miles. If a railway could be built from Mercury to the sun, it would take a train going a mile a minute over sixty-eight years, or a man's lifetime, to go to the sun.

When we look at Mercury through the telescope we see it has phases like our moon—quarter full, half full, and full. When it reaches the side of the sun nearest to us, its dark side is toward us and we cannot see it, since the sun is shining on the side turned toward him. When Mercury gets round to the farther side of the sun, however, we see its full-moon shape.

Mercury is a smaller planet than the Earth, its diameter being three thousand miles, while the Earth's is nearly eight thousand miles. A man who weighs one hundred and fifty pounds here would weigh only about thirty-seven pounds on Mercury, as gravity varies according to the bulk of the planet.

The planets which are closer to the sun revolve round it more quickly than the others. Mercury goes round the sun four times for our once. So eighty-eight days is the length of a year on Mercury. This planet gets more heat and light than any other members of the system, because the nearer we are to the fire, the warmer and brighter it is.

Through the telescope astronomers found certain marks on Mercury. By these they have proved that this planet always keeps the same face turned toward

the sun, just as our moon always keeps the same face toward the Earth. From this we know there is perpetual day on one side of Mercury and perpetual night on the other.

The sun shines about seven times as strongly on Mercury as on the Earth. The sunny side of the little planet is exposed all the time to this fierce glare, making the heat above the boiling-point. If there were ever seas on that side, they have long since boiled away. But on the dark side everything must be cold and frozen, two or three hundred degrees below the freezing-point. If anything lived on this dark, cold side, it would never get any light except from the stars.

It was not till after the telescope came into use that much could be known about Mercury. Then astronomers began to trace its path and to foretell when it would pass between us and the sun. For years they worked on their theory, but the planet never appeared just when they said it would. It was always early or late, which showed that they had not yet solved the problem.

It was in 1627 that a great astronomer called Kepler predicted that on 7th November of that year at a certain hour Mercury would cross between the Earth and the sun. Kepler said we should then see it as a little dark spot moving across the bright sun's face. Nobody was sure that Kepler was right, but Gassendi,

another astronomer, prepared to test Kepler's theory. He set his telescope and began to look on 5th November. All day he watched. Next day at sunrise he resumed his task, but Mercury did not appear. Then came the 7th of November, but at the hour that Kepler had named there was no sign of Mercury. But five hours later the planet passed across the sun's face. Kepler had missed the correct time by only five hours.

Astronomers were now able to correct their miscalculations and to mark Mercury's path out exactly. The planet does not move in a perfect circle, nor does it always move at the same rate. When Mercury is nearest the sun it travels thirty-five miles a second, but when farthest away only twenty-three miles a second. This is what made the problem so difficult.

Besides its motion, we know very little about Mercury. It is one of the planets that has no moon. It has an atmosphere that contains water vapour like that of the Earth, but we have never seen any clouds. If it has no clouds, then it can have no rain or snow.

VENUS, THE EVENING STAR

Next to Mercury in distance from the sun comes Venus, the most brilliant of all the planets, which glitters in the sky like a pure diamond. Through the telescope, Venus shows all the phases or changes of the moon. Like Mercury, it may be either a morning

star or an evening star. When the moon is not shining Venus is so bright that it casts a shadow at night, and this planet may sometimes be seen with the unaided eye in full daylight.

Venus is only a little smaller than the Earth, and might be called the Earth's twin sister. It is about sixty-seven million miles from the sun, and goes round the sun once in about seven and a half months, or two hundred and twenty-five days. As it is nearer the sun than we are, Venus receives almost twice as much light and heat as the Earth, but only a third as much as Mercury.

Many astronomers think that, like Mercury, Venus always keeps the same face turned to the sun. Then it must have perpetual and frozen night on the side away from the sun, and perpetual and scorching day on the side toward the sun. We are not sure about this, however.

Astronomers tell us that Venus has an atmosphere a little rarer than ours, and that the weather there is fearful beyond words. Violent windstorms blow continually between the hot and cold sides of the planet. This being so, Venus would be a very unhappy globe to live upon.

The surface of Venus is so bright as to be difficult to study with a telescope. The light of the sun is reflected to us by such dense masses of cloud and dust

that it is almost impossible to trace any permanent markings on the planet and thus to find out how long it takes to rotate on its axis. Occasionally Venus passes between the Earth and the sun, giving us what astronomers call a 'transit of Venus.' The planet can then be seen by the naked eye as a black spot on the sun's face, crossing it from east to west. The last transit occurred in 1882, and the next is not due until 8th June, 2004.

Except for the moon and an occasional comet, no other heavenly body comes so near the Earth as does Venus. Yet we know less about Venus than about Mars; the reason being that when Venus is closest to us it is between us and the sun, and its dark face is turned toward us.

MARS, THE WAR PLANET

After Mercury and Venus in distance from the sun, is the Earth with its one frozen moon. Next we come to our neighbour, the planet Mars. Mars is smaller than the Earth, being only forty-three hundred miles in diameter. The Earth would make seven planets the size of Mars.

Gravity on Mars is only two-fifths of what it is here. So a boy who weighs eighty pounds here would weigh only thirty pounds there. But if he could jump five feet here he could jump thirteen feet there.

In 1873 a new telescope with a 26-inch refractor was built at Washington. It was at that time the largest telescope in the world. A few years later (1877) Mars came round to its nearest point to the Earth, and Professor Hall turned his big telescope on it. On 11th August he detected a minute speck of light near the planet, and a few days later he discovered it was a little moon passing round Mars; it moved very fast. The next evening he discovered a second moon.

One of these tiny moons is six miles in diameter and the other seven miles. One makes its trips round Mars in about seven hours and the other in thirty hours. A day on Mars is about twenty-four and a half hours, so one moon goes round three times every day and the other about once a day. The former goes through all the changes from new moon to full moon in one night.

Mars never passes between us and the sun because it is farther from the sun than the Earth. So Mars does not change like our moon, but is always full.

A year on Mars is six hundred and ninety-seven days, or nearly two of our years. If you lived on Mars, you would be only half your age. Our neighbour has seasons like ours, but they are nearly twice as long. The winter season we should think would be bitterly cold because, owing to its greater distance from the sun, Mars receives less than half the light and heat

that comes to the Earth. Yet Mars seems to have a milder climate than we should expect, because, so far as we can judge, the water is never frozen except very near the poles. Clouds are rarely seen. In 1894 an area larger than Europe was hidden from our view. Whether or not it was raining, we cannot say. The screen may have been mist or a dust-cloud. Astronomers say that on Mars there are not such fierce storms and cyclones as we have here.

When nearest the Earth Mars is thirty-five million miles away, and when observed with a telescope magnifying one thousand times it is brought to a distance of about thirty-five thousand miles. It then appears only six or seven times as large as does our moon to the naked eye, and it is difficult to distinguish the details and markings. We can see two white polar ice-caps, which disappear in the summer. This truth proves that the summer there is warm enough to melt all snow at the poles. We can see orange-coloured regions which may be deserts, and blue-green areas which change to orange in the autumn and winter of Mars. These blue-green areas may be some kind of vegetation which fades as the Martian year wanes.

The planet is covered with a network of fine lines, which some astronomers have called *canals*. They seem so straight as to make some believe that they are the work of intelligent beings. There are no mountains

on Mars, the surface being surprisingly flat. The Martian sky is usually clear like that of a desert land, except that there is a haze about the poles just after the snow has melted. The planet also appears to have dust-storms.

One of our leading astronomers feels sure that Mars is inhabited by beings of some sort or other, but whether they are like us or far different nobody can say. This authority thinks they are intelligent beings and have perhaps dug the great waterways on the planet.

Other astronomers, however, say they find no water vapour in the atmosphere of Mars. They think that as the atmosphere of Mars is certainly scanty, and the distance from the sun is so great, it may be too cold for fluid water to exist on the planet.

Some of these disputes may be settled when Mars next comes to its nearest point to the Earth. It is interesting to think that Mars is inhabited by intelligent beings, and that we may yet learn to communicate with them by some wireless code, and, in return, receive messages from the crimson planet to which we have given the name of the Roman god of war.

JUPITER, THE KING OF PLANETS

From Mars we come to Jupiter, which, next to Venus, is the brightest planet. It is larger than all

the other planets put together, and is thirteen hundred times as large as the Earth. If we chose a marble to represent the size of the Earth we should need a football to do duty for Jupiter. This planet is eleven times greater in diameter than the Earth, and five times farther from the sun.

Jupiter, unlike most of the planets, is brightest in the centre. This leads astronomers to think that Jupiter may still be a hot ball—so hot as to increase the sunlight which it reflects. Its temperature is said to be above that of boiling water. The planet is concealed most of the time by clouds, but there are times when the clouds part and the central globe can be seen. The clouds appear to fly at a terrific speed. Great cyclones drive forward at a rate of two hundred miles an hour, and last seven weeks or more.

Jupiter receives too little heat from the sun to account for all that is going on there. Some think that the heat necessary to produce these changes must come from the planet itself. The colours of the changing clouds seen through the telescope are said to be remarkably beautiful.

While Jupiter seems a boiling planet, it is still young and may, in the course of millions of years, cool down so that plants and animals may come to live upon it. Jupiter revolves once in about ten hours, which is a day on that planet. The night lasts but five hours.

Jupiter completes its journey round the sun once in twelve years.

The most wonderful feature of Jupiter is its system of bright moons, four of which were seen by Galileo with a small telescope. The fifth moon was discovered by Professor Barnard from Mount Hamilton in 1892. This last one is difficult to see, for it is only one hundred miles in diameter and is so close to its parent that it is lost in his glare.

A few years later two more moons were discovered from Mount Hamilton with the aid of a photographic plate. Later still, in 1908, the eighth moon of Jupiter was discovered from Greenwich.

Anyone having a telescope can enjoy watching the larger moons of Jupiter. They disappear behind the planet and come forth again on the other side. Then they pass in transit across Jupiter's face like little black dots.

By measuring the movement of Jupiter's moons astronomers made a remarkable discovery. They found out exactly how long it takes light to travel from Jupiter to us. So we now know that light travels 186,400 miles a second. This fact has been a great aid to science in many ways.

SATURN, THE RINGED PLANET

Saturn is a beautiful object seen through the telescope, for it has ten moons and a wonderful system of

Uranus was not in the exact place where it was expected, and again in 1840 it did not keep the appointment.

The attraction of some unknown planet was thought to be the cause of the mysterious deviations by Uranus in the course which, according to calculations which had proved reliable in regard to other similar mathematical problems, the planet must take, and a brilliant young mathematical graduate of Cambridge University, John Couch Adams, devoted two years of intensive study to the question. At last he had worked out on paper an answer to the formidable problem, and was convinced that his solution would prove accurate. But he had no telescope at his command, and when in October 1845 he endeavoured to induce the Astronomer-Royal at Greenwich Observatory to test his conclusions he was not taken seriously. Meantime a French astronomer, Urban Leverrier, unknown to Adams, was also investigating the riddle, and he concluded his calculations in June 1846. He was more fortunate than the young Englishman, for when in the following September he asked the Director of the Berlin Observatory to point his telescope to the spot in the heavens where both Englishman and Frenchman declared that a new planet would be discovered this was immediately done, and Neptune was found.

But for the lack of interest at Greenwich Adams would be honoured as being the first to demonstrate

the planet's existence. As it is he shares this honour with Leverrier, although the Frenchman's discovery was announced first to the world.

Thus Neptune was discovered less than one hundred years ago. It appears to be a very small globe, and in the telescope it looks greenish—not as yellow as Uranus, and not nearly so bright. It appears small because it is so far off, but the diameter is thirty-five thousand miles, more than four times the Earth's diameter.

Neptune revolves round the sun in about one hundred and sixty-five years in a mammoth circle, a great distance from the sun. When we look at it through the telescope we can see no marks upon its face. Possibly it is surrounded by an envelope of clouds, and it may be hot; if this is true it is not yet a fit place for anything to live, but we have no certain knowledge of these things. Neptune has one moon.

CHAPTER VIII

THE STARS ARE SUNS

THE stars are all suns and shine by their own light. Some of them appear very dim to us, because they are so very far off. If we were near them they would be bright and hot like the sun. Only the sun looks large to us, and we receive its heat because it is near. The stars look small because they are so far away. We get no heat at all from the stars, though we do get a little light.

It is very hard for us to comprehend how very far away from us is the nearest star. The distance is so great that it has to be measured by the rate at which light travels, which is 186,400 miles per second. Light requires, coming at this amazing speed, about eight minutes to travel from the sun to the Earth, but it requires more than four years for light to reach us from the nearest star. Most of the stars are too far away for astronomers to measure the distance, but you may be interested to learn that the light from the Pole Star which reaches your eye must have started on its journey shortly after the Crimean War, while that from the Pleiades may have set forth before Columbus started on his great voyage.

Suppose you go out some night and look at the sky with the naked eye. Choose a small space and count the stars in it; then take a common opera-glass and look again, counting the stars that you see in the same small space, and you will have many more. A large telescope will show you a thousand times more than you are able to see with the opera-glass.

The astronomers have counted all the stars that they can see. We do not know just how many others there are. We can see six thousand with the naked eye, but we cannot see them all at one time. With our largest telescope we see a hundred million stars.

In the universe is room for everything. We cannot imagine an end to space. All the stars that we see on a bright night are in endless space. It is supposed that many of them have planets moving round them just as the Earth and the other planets move about our sun. We are not certain that this is true, but why should it not be so? If each of the stars that can be seen had a family of eight planets, then there would be eight hundred million planets. Very likely there are stars having only two or three planets, and there may be some that have none—childless stars, we might say.

If the stars have planets about them the planets do not shine by the light of the stars. So it would be impossible for us to see them even with our most

powerful telescope. If we were standing on the star nearest to us we could not see our Earth, because the Earth only reflects light, and it would be far too dim. Therefore, if you would like to do so, you may believe that the other stars have planets about them, and that these planets have men upon them. No one can prove that you are wrong, and you cannot prove that you are right.

If our Earth stood still the stars would seem always to keep in the same place in the sky; but, nevertheless, they are all moving through space just as our sun and his family are doing. The stars are so far away that although one of them should move a million miles a day, it would be years before our astronomers could detect a change of position. We are told that our sun and the planets are moving through space at the rate of eight hundred miles per minute.

CHAPTER IX

COMETS AND SHOOTING STARS

We know that the Earth and her sister planets move round the sun in circles—or *almost* circles—called *ellipses*. There are other bodies in the heavens which also swing round in great ellipses. They approach the sun at some part of their path, and then they move far, far away—farther than the most distant planets. These bodies are called *comets*.

The comet is a beautiful object with a head that sends off a very bright light. It has a flaring tail which grows fainter as it leaves the head. The tail extends from the side opposite to the sun. The head of the comet must be nearly twice as thick as our Earth in order to be large enough for us to discover it with our telescopes. Some of the comet heads have been measured, and one is thirty-one times larger than the Earth. Another is one hundred and fifty times as thick as our Earth. Some of the tails are so long that they could reach from the Earth to the sun.

Some comets have regular courses. They appear and then disappear for several years and return. Astronomers have measured their courses and can tell when they will appear again. Halley's Comet comes

back once in every seventy-six years. There are others that will not come back for a thousand years, or for many thousand years.

Another thing that we have found out about the comets is that they are not able to hold together. They break into pieces. Some of these pieces become cold when they get out into space, and harden into lumps. Sometimes these lumps, whirling in their own way, follow the same track as the comet. If the comet should break into many pieces it would make a group of these lumps all going in the direction and in the same path about the sun.

The tails of comets are so thin that our Earth actually passed through one once, and no one but our astronomers knew anything about it.

As we have walked out in the evening we have all, at one time or another, seen a falling star. A falling star sometimes leaves a trail of light behind it, and we wonder which of the beautiful stars of heaven has fallen. But astronomers tell us that no real star falls. What we saw was a lump of matter of which the comets are made. While it was following its own swift path round the sun it got so close to the path of our Earth that the Earth drew it down by gravity. So this bit of world-stuff fell to Earth.

It was just a cold, dark lump of stone or iron, too

small for us to see until it reached our atmosphere. When it began passing through our air, which was thick enough to cause friction, the cold lump was raised to a white heat and burned up, just as a match scratched on sandpaper burns. When it began to blaze we saw it, and said, "There is a shooting star." By the time it had come within twenty or thirty miles of the Earth it was entirely consumed. Sometimes the lump is so big that there is not time for it to burn up while passing through the two hundred miles or more of our atmosphere, and what is left of it strikes the Earth with such force that it buries itself in the soil.

These lumps are called *meteorites.* If they strike the Earth they are called *meteors.* We may see them in some of our museums. Strangely enough, they have no new metals or elements with which we are unfamiliar. The elements are the same as we have on the Earth, but they are sometimes combined differently. In the garden of the Natural History Museum, South Kensington, there is a large meteorite which fell in Hyde Park. It was fortunate that no man stood where this meteor struck the Earth.

If it were not for the air which wraps our globe like a great blanket and through friction fires these meteors, and destroys them before they get to the Earth, we might all be pelted to death. Professor Newton tells

us that in every twenty-four hours our world meets seven million of these shooting stars. Some of them are no larger than shot, and others weigh tons. But they generally burst into fragments and fall or burn without doing damage.

CHAPTER X

THE STORY OF THE SEA

Three-fourths of the surface of our planet is covered by the sea, which both separates and unites the various races of mankind. The sea is the great highway along which man may journey at his will, the great road that has no walls or hedges hemming it in, and that nobody has to keep in good repair with the aid of pick-axes and barrels of tar and steam-rollers. The sea appeals to man's love of the perilous and the unknown, to his love of conquest, his love of knowledge, and his love of gold. Its green, and grey, and blue, and purple waters call to him, and bid him fare forth in quest of fresh fields. Beyond their horizons he has found danger and death, glory and gain.

In some great continents, such as America, and Australia, there are towns and villages many thousands of miles from the coast, whose children have never seen—or heard—or felt—the waves of the sea. But in the British Isles it is nowhere much more than a hundred miles from the most inland spot. The love of the sea is in the very blood of the British people.

The great surface of the sea seems about the same everywhere, but its floor is very uneven. It has

mountains and plains like the continents. Here and there are great deeps like tremendous saucers. At other places are hills and valleys. On the ocean floor are mountains whose lofty summits rise to the surface of the sea and form islands such as the Hawaiian group.

We know that the average depth of the sea is about two and a half miles, but in a few places it is very deep indeed—over six miles. If the highest mountain in the world, Everest, which is nearly six miles high, could be placed in this deepest place in the Pacific, the mountain-top would still be more than a half mile under the surface of the sea.

The sun shines hot on the broad waters of the ocean, but its power affects only a thin layer on top, perhaps a hundred feet deep. This heated layer of ocean water travels in great currents like the Gulf Stream. The deeper waters of the oceans even near the equator never feel the sun's rays, but remain near the freezing-point of fresh water from year to year. At the depth of a mile there is no sunlight whatever. There it is always winter and always dark.

The air presses upon our bodies with a weight of about fifteen pounds to the square inch at sea-level. We are used to this air pressure and do not notice it. In the sea this pressure is doubled at a depth of thirty-five feet, and it increases at this rate for greater depths. In the great deeps off the Philippine Islands, a man

would be squeezed and utterly crushed by a pressure of several tons per square inch.

The pressure near the ocean floor is so great that if you were to weight a piece of wood and lower it to a great depth and then pull it up again it would no longer float, for it would have become waterlogged. All the tiny wood cells and cavities would have burst and become filled with water.

We know that animals live at a depth of three miles and more, and we wonder how this can be. The bodies of animals down there are almost entirely filled with water, and this saves them from being crushed. However, many of those animals contain some gases as well, for when they are captured in nets and drawn to the surface this gas expands until the animal actually explodes. Its body is torn to shreds as it bursts.

Why is the sea salt, and where did the salt come from? The rain found it upon the land first, and the rivers have carried it to the sea. When the water of the sea evaporates and rises in clouds again, it leaves the salt behind. There are about three and a half pounds of salt in every hundred pounds of sea-water. Salt makes the water of the oceans heavier than the fresh water of rivers and lakes. It is easier to swim in salt water than in fresh water.

In the Far North the winter sea is covered with ice, which is heavier than fresh-water ice because of the

salt. Still it is able to float and to bear the sledges of the Eskimos and the explorers. The salt ice sheet is broken by the tides into *pack ice*, which is often piled into mountains.

In the Arctic summer, when the sun does not set, the ice plane breaks up into *floe ice*, which drifts southward until it melts. Icebergs which break off from the lower ends of glaciers also float southward in huge masses, or islands, often several miles in width. Bergs have been reported that were thirty miles long. Only about one-sixth of the iceberg appears above the surface of the ocean. Large icebergs tower from one hundred to two hundred and fifty feet above the sea. The largest ones are found in the Antarctic Ocean.

As the icebergs drift away from the poles toward warmer waters they often invade the paths of ships, and in times of fog cause fearful collisions. The greatest disaster of this kind ever recorded was that of the *Titanic* on 14th April, 1912. The *Titanic* was the largest ship in the world at the time. She was sailing on her maiden voyage from Southampton to New York with more than two thousand passengers and crew. Striking the iceberg without warning in the fog, she sank quickly. More than fifteen hundred lives were lost.

The life of the ocean is very interesting. There is said to be far more living matter in the sea than there

is in all the rest of the world. Sea-water is full of millions of tiny plants, and fish live upon these and upon one another.

The largest sea animal is the whale, which is the giant of the animal world to-day. Its tail is so powerful that with a single blow it can destroy a large boat. Sperm-whales and right whales may be from fifty to seventy feet long, and there are others still larger. The blue whale reaches a length of ninety feet with a weight approaching seventy tons. Very few are found in these days except in the South Seas.

The ancestors of whales, it is said, lived on land, for they still have slight traces of hind-legs. They are warm-blooded animals, and feed their babies as land mammals do. But ages ago whales changed their home—moving from the land to the sea. The whale is suited to live in water. He is shaped like a submarine boat, with a tail turned into a powerful paddle. He has flippers on his sides to keep him balanced and layers of fat or oil under the skin called blubber, which furnish heat and make the huge body light and buoyant.

The whale has blow-holes with valves on the top of his head so that he may get air easily when he comes to the surface. He has an enormous chest and lungs that take in a great quantity of air at one time. When he comes up to breathe he generally stays on the surface

about two minutes, during which he blows several times and then disappears.

The right whale may remain under water for half an hour or more, which is a wonderful performance for an air-breathing animal. On a sea voyage you may frequently see whales 'spouting.' They are only blowing out from their lungs the used-up air which carries up a little spray of water with it.

The whale's eyes are no larger than those of an ox, but he can see well under the water. When in search of food he swims with his mouth open. The water is forced out through the fringes of whalebone round the jaws, leaving the catch in the mouth.

One of the odd-looking birds of the ocean is the penguin, which is well fitted for sea life. It is found in the cold regions of the Antarctic Circle. Penguins cannot fly. Their wings have been changed into swimming flippers, which they use like oars. With the aid of the flippers they can dive to a depth of thirty feet.

Penguins spend no more time on land than is necessary for sleeping and for rearing their young. Their food consists of the small creatures of the sea, which they catch by diving, often to great depths. They use their feet not as paddles, but as rudders to guide them. Under their skin is a layer of fat which, like blubber, helps them to withstand the icy water in which they live.

Some gather stones and sticks for a kind of nest; others make no nest whatever. A single egg is laid, and both father and mother bird take turns in sitting upon it. When hatched, the mother guards the penguin chick with great care, keeping it with her for a year. Though they cannot fly, the penguins make long voyages along the Antarctic shores every year, swimming like the seal.

There are hundreds of interesting sea-birds, like the pelicans, gulls, the petrels, and cormorants, but we have no space to tell about them here.

The strangest haunts of life are in the deep sea, by which is meant the floor of the deepest part of the ocean and the layers of dark water near the floor. Life is found six miles below the surface, where the water pressure is enormous—more than six thousand pounds to the square inch. It is very cold there—always about zero. It is also absolutely dark except for the fitful gleams of some fishes which, like fireflies, give out light of their own. It is too deep and dark for any plants to grow, because plants need light, but no depth, it seems, is too great for animal life.

As there are no plants at this depth the animals must feed upon one another. The struggle to live is keen. The stomachs of some of the fishes stretch amazingly, so they may swallow objects larger than themselves. When a whale or a porpoise meets death in the ocean

and sinks to the bottom there is a great feasting by millions of living things till the monster is devoured.

The sea swarms with strange and curious animals prowling about in the dark, some with long feelers and some with long limbs like stilts. Then there are the cuttlefishes and true fishes stealing along. Certain kinds here are blind. They depend upon great feelers to get about and capture food.

In the blackness of the deep sea many animals produce their own lights. This light may attract other fishes wanted for food. But some deep-sea fishes have very large eyes so as to see in the dim light that they themselves make. Some of these animals have been brought up by dredges at night, and it is said that on these occasions "they gave off flashes of light, beside which the twenty torches used for working light were pale." Some of these animals were carried into the laboratory where the lights were turned out. These creatures threw out brilliant jets of fire which changed from red to orange. Others shed green lights.

Many fishes have these light-giving spots. Some are called lantern fishes. They shine starlike in the black deep. One kind has a luminous snout like the headlight of an engine. One cuttlefish has about twenty of these luminous spots. Another fish has two bright plates just under its eyes. One of these gives off red light and the other green. It is thought that the

fish has control over them, and can turn its lamps on or off when it pleases.

Some deep-sea fishes have rows of light spots, and as they swim they resemble lighted steamers or railway trains at night.

Several kinds of fishes like eels and rays have the power of generating electricity, which they use to protect themselves. In some cases fishes can discharge enough electricity to paralyse a much larger animal than themselves. It is believed, too, that these fishes use electricity to capture their prey.

One animal that divides its time between the water and the shore is the seal. It not only comes on shore to rear its young, but for resting purposes at any time. The shape of the seal and its smooth fur make swimming easy by avoiding friction with the water.

As the seal glides along the hind-legs are thrown backward beside the short tail to form a propeller. Its nostrils can be closed under water; the sensitive whisker hairs are used as feelers in the dark sea. The seal has blubber to buoy it up and to furnish heat, and this same blubber is a store of food upon which it lives when the weather is too stormy for fishing.

The common seal can swim ten miles an hour. Baby-seals have to be taught to swim, and do not take naturally to the water.

There are many sea-birds that spend part of their

time ashore, such as gulls, terns, cormorants, sandpipers, and curlews. Then there are many seashore fishes, which have strange names as well as queer habits. There are also crabs and lobsters and shrimps, and many other shellfish. Starfish and sea urchins cling to rocks and stones near the shore. Near Catalina and other islands of the Pacific Ocean we may study sea life through glass-bottomed boats.

Many years ago treasure ships sank to the bottom of the ocean, and their riches were lost. In shallow seas a diving-bell came into use some years ago to reach such treasure. One of the early uses of this invention occurred in 1683, when William Phipps offered to search a rich Spanish wreck near an island in the West Indies. Charles II of England gave him a ship to use for this purpose. He made the attempt, but returned unsuccessful and in great poverty.

Still Phipps said he believed it could be done. He asked the King for another ship and was refused. Then Phipps went among his friends to get the money for another trial. Many laughed at him, but finally enough money was subscribed, and five years after his first attempt he set out again. By using a diving-bell, he brought up from the wreck, forty feet below, treasure enough to make him and all those who aided him wealthy.

A diving-bell is a strong, heavy vessel of wood or

metal, made perfectly air- and water-tight at the top and sides, but open at the bottom. When it is lowered carefully into the water the air in it cannot escape, and therefore the bell will not fill with water. Thus a man may descend in this bell, breathing the air in it, and work for several hours. When the air becomes bad, fresh air is pumped into it through a tube. When the bell is at a depth of thirty feet, the pressure of the water compresses the air into one-half its former volume, and so the bell becomes half full of water. Thus the bell cannot be used in very deep water. Diving-suits are now made in which divers have gone down nearly three hundred feet and recovered the cargoes of shipwrecked vessels. Submarines to-day roam about in the depths of the ocean.

It is well known that the sea is the cheapest of all highways, for there is no cost for upkeep as there is for railways, and no upstream pull as in rivers. The ocean steamer can strike off in any direction. Every nation desires as many sea-ports as possible.

As bays and gulfs enable ships to go far inland for their cargoes, a country with a deeply indented coast-line has the advantage of cheap transportation. Many wars have been fought by nations, like Russia, which have few sea-ports, to get more harbours on the sea. One of the causes of the Great War was Germany's desire for a longer sea-coast and better harbours.

Though the sea covers about three-fourths of the world's surface, it furnishes, except fish, a very small part of man's food. However, it was the fish of the sea that first led man to sail the ocean, and in searching for good fishing places the sailors found new lands far beyond their former ken.

CHAPTER XI

THE EARTH'S ATMOSPHERE

We are all living at the bottom of a great ocean of air which extends many miles above our heads.

We have at last learned to travel in this ocean. The first aeroplane to stay in the air was built by Langley in 1896. His ideas were later improved by the Wright brothers. Orville Wright first flew for twelve seconds on 17th December, 1903.

This early machine was fitted with an engine of only sixteen horse-power and flew about thirty-five miles an hour. To-day we have aircraft fitted with engines having over fifteen hundred horse-power, and flying at speeds of nearly five miles per minute.

Twenty years after the first flight by the Wright brothers very long flights were made. The first of these was that of Alcock and Brown across the Atlantic, the air-journey being made in just sixteen hours against the normal period of six days by sea. Then in 1923 Kelly and Macready made the first non-stop flight of twenty-seven hours across the United States from New York to San Diego, a distance of twenty-seven hundred miles. In 1926 Sir Alan Cobham flew to Australia and back, a distance of some twenty-eight thousand miles.

The difficulty with long flights has been that the lift of an aeroplane is limited, and if most of the weight is taken up by fuel, very few passengers and very little cargo can be carried. With short flights larger loads can be transported, because less fuel is necessary. Modern aircraft can now carry loads upward of twenty-four tons, fly at two hundred miles an hour, cover distances of over two thousand miles without stopping, and rise to heights greater than Mount Everest (29,002 feet).

Airmen have conquered every handicap of the atmosphere but fog, and there is promise of overcoming that. On several occasions when the wind has been so rough that steamers were stormbound in the harbours, aircraft have safely made the journey between London and Paris. When the country is fog-bound, however, flying becomes dangerous, because the pilot is unable to see the ground and cannot choose a safe spot for landing. He may crash into a building or a tree before he can see the nature of the ground.

The ocean of air may yet become as well known and as much used for travel as the oceans of water.

As we ascend in an aeroplane or climb a mountain from the level of the seashore, the air becomes less dense, until at a great height it is so thin that it cannot support life. At a height of twenty miles the air is very thin indeed. The men who endeavoured to climb

to the top of Mount Everest took oxygen gas with them; without it they could not have exerted the great efforts called for by their difficult and laborious task.

The highest point to which any bird can fly is about five miles. The condor, we are told, can struggle up to that height, but most small birds and insects which are carried up by aeroplanes or balloons become insensible much below that level.

In 1920 men had flown in aeroplanes to a height of over six miles, while balloons with men in them had ascended about seven miles, but the men suffered very greatly. In some cases they became unconscious before this height was reached. In other cases, where oxygen was carried for breathing, the chief discomfort was from cold.

Small balloons containing only recording instruments have risen higher than sixteen miles. At this height the air is still dense enough to carry the balloon.

When 'shooting stars' enter the Earth's atmosphere they are suddenly chilled, for the temperature of outer space is thought to be about four hundred and fifty degrees below zero, Fahrenheit. In passing through the atmosphere, as we have read, meteors are heated by friction with the air, and when they become red-hot they may be seen. The height at which they begin to glow has been calculated in some cases, and found to

be nearly two hundred miles above sea-level. This shows that the atmosphere is much more than two hundred miles deep, for the meteors must have come a long distance through the thin upper air before becoming red-hot by friction with it.

The air itself is a mixture of gases, the chief of which, in the lower layers, are nitrogen and oxygen; much smaller quantities of carbon dioxide and water vapour are also present, together with a few other gases. In the upper layers of the atmosphere hydrogen and helium are both believed to be present.

Of late a great deal of study has been devoted to the air at different levels. Balloons are used in this study. One kind of balloon which is used is set free and rises till it bursts. Then the instrument that it carries falls to the Earth. A light bamboo framework round the instrument keeps it from injury when it strikes the ground. The remnant of the balloon also acts as a parachute to make the instrument descend slowly. In this way the records made high in the air usually reach the ground in good order. A notice is attached to the instrument, in case it should not be immediately recovered, offering a reward to the finder who returns it to any post-office. Records have been obtained of the temperature and pressure of the air higher than sixteen miles above the Earth's surface.

These records have a very curious story to tell us.

In days gone by it was believed that the higher we ascend the colder it becomes, until the extreme cold of outer space is finally reached. But this is not so. The temperature does diminish with height until a certain level is reached, but above this level the temperature remains practically unaltered, as far as our balloons have yet gone. This level in our latitude is about seven miles; at the equator it is ten miles, and at the poles about five miles.

All the teeming life on our planet is rendered possible by the thin zone or layer of air about three miles deep at the equator and thinning out northward and southward till it ends at the ground-level in the neighbourhood of the Arctic and Antarctic Circles. Of all the extent of our atmosphere, this thin zone only has a temperature above freezing-point.

We all know that the wind has power to drive ships or to blow down trees and buildings; but for a long time no one knew that the air had weight, or that it pressed down upon the Earth.

Galileo was one of the first to conceive a correct idea about air pressure. He had a suction-pump which would not work when the water was low in the well. He sent for a mechanic to repair it, but was told that the pump was in good condition, and that no suction-pump would lift water much over twenty-five feet. Why this was true the mechanic could not explain.

Galileo believed the reason was that the air pressure was not great enough to raise it any higher.

Galileo set one of his pupils, named Torricelli, to work on this problem. Torricelli proved that Galileo's idea about air pressure was correct. He showed that at sea-level it will support a column of water about thirty-four feet high. If we had a suction-pump that would create a perfect vacuum it might raise water that height; but no suction-pumps can make a perfect vacuum.

Torricelli took a glass tube about three feet long, open at one end and closed at the other. He filled it with mercury, which is a very heavy liquid, being 13·6 times as heavy as water. Then, holding his thumb over the open end, he inverted it in a cup of mercury. He was careful not to remove his thumb till the lower end of the tube was well below the level of the mercury in the cup. The column of mercury in the tube dropped till the top of it was about thirty inches above the level of the mercury in the cup, and remained there. You would have expected the mercury to run down into the cup, but it was held up by the air pressure on the mercury in the cup. Thus Torricelli taught us to measure air pressure by a column of mercury in an instrument called a *barometer*.

Blaise Pascal, a Frenchman who lived about the same time as Torricelli, discovered how to tell the elevation

of a place by using a barometer. He and some friends took with them a barometer and climbed a mountain. They found that, as they ascended, the column of mercury slowly fell in the tube. Then when they came down the mountain, the mercury rose again toward the thirty-inch level. Thus they proved that the higher we ascend from sea-level, the lower is the air pressure.

CHAPTER XII

THE STORY OF ANIMALS

THE animal life of the land-world includes mammals, birds, and reptiles. A bird is a warm-blooded, feathered animal, laying eggs from which its young are hatched. A reptile is a cold-blooded animal, covered with scales or with a bony shell, and, like the bird, laying eggs. A mammal is a warm-blooded animal whose young are born alive, and are nourished by the milk of the mother. Certain mammals, such as the hippopotamus, are what is called *amphibious*, able to live either on the land or in the water. All breathe with the aid of lungs, and all, except a very few, have hairy coats. The only sea-dwelling mammal is that vast and mysterious creature, the whale. All the land-dwelling members of this division have four legs, with the solitary exception of the most wonderful of all—man.

In Australia there is found an exceedingly odd creature, the duckbill or platypus, which combines the characteristics of a mammal and a reptile, as it lays eggs, has webbed feet, and *yet* is covered with fur.

There are thousands of species of mammals on the Earth, both wild and tame. Man became civilized only as he learnt to make use of other animals. It was

largely by mastering the wild beast that he made progress. With the strength and power of the animals which he domesticated and taught to work and do his bidding, he conquered the soil and provided himself with food and clothing.

The cud-chewers, and the hoofed animals, such as the cattle, horse, and sheep, have been most easily domesticated. No domestic animals eat flesh except the dog and cat.

Even the half-civilized people of the world are dependent upon some beast of burden. The Eskimo trains the dog to drag his burdens over the snow and ice. The Lapp employs the reindeer to pull his sledge and to furnish him with milk. The Indians of South America use the gentle llama. The people of middle Asia have the yak, and the men of the desert the camel; while the people of India have trained the clumsy elephant to lift logs, draw burdens, and carry men through the jungles on hunting trips.

Both wild and domestic animals have furnished man with warm clothing so that he may dwell in cold climates. For many years wool, silk, or skins were the chief source of men's clothing. It was only a few hundred years ago that cotton came into use. Leather has always furnished a protection for the feet, and nothing has been found to take its place.

The larger part of the plants that grow on the Earth are not suited for the food of man, but the cud-chewing animals thrive on grass and herbage, and turn it into milk, from which butter and cheese are made. Cattle, sheep, and pigs provide us with most of our meat. Beef, mutton, and pork, along with poultry constitute a large part of our diet. Every part of the animal may be turned to some account. The hair is used in the plaster of our houses, the hoofs are used for glue, the hides for leather, and the bones for button-making, or to fertilize the soil.

We do not know when the horse was first tamed. In early days we know that he was wild and lived in the open country. We know that he lived in the time of the cave-man, because we find pictures of him scratched on stones and sand-drifts. The horse was smaller than he is now. His earliest-known remains, found as fossils in the rocks of the Tertiary Period, show that at one time he was less than a foot in height, even when full grown. We still find a small horse in cold, bleak lands. The pony of the Shetland Islands is the best-known small horse.

Horses were first used by kings, nobles, and warriors to ride upon. The Greeks and Romans harnessed them to their chariots. The farmer for many ages did his work with the slow plough-ox, until at last the swifter-moving horse was hitched to the plough and

wagon. There are many countries where oxen are still used for ploughing.

Years of careful breeding have produced the strong draught horse, the lightly built racehorse, and the many beautiful beasts of burden in use to-day. The horse is very faithful and intelligent. If trained when a colt he can be easily broken to harness, and will follow commands. Some horses give good service for twenty-five years.

In the days of the cave-man there were also wild cattle. The cave-man at first killed them for meat. Perhaps he kept the calves for pets. Then he tamed them and kept them for their milk. While the milk was being carried in skin bags the cream became jolted into butter; this was a great discovery for mankind. Then we find early man becoming a herdsman. He harnessed oxen and made them beasts of burden. With a crude plough they were used to turn the soil for sowing. To-day we have certain types of cattle especially bred for their milk, and other larger kinds that are killed for beef.

Sheepskins made delightfully warm clothing for man in early times. On the plains of Asia to-day there are still wild sheep that are killed for their flesh and wool. Sheep are bred in great flocks in many parts of the world. Australia is one of the countries where sheep-breeding is practised on the largest scale. They can live on

rough hillsides and mountain-tops where other domestic animals would starve. They supply the world with wool, and their skins are used for clothing and shoes.

Our hogs of to-day came from the fierce wild boars that roamed years ago through the forests of Europe, living on nuts and rooting in the earth with their long snouts. They were dangerous beasts to hunt with only clubs and bows and arrows. We may well wonder how this fierce animal was tamed and made into the fat and lazy 'porker' of the pigsty.

Our chickens probably came from the wild jungle-fowl of India. Early man used to snare the large wild birds for food and robbed their nests of eggs. When he settled down to herding flocks he tamed this wild-fowl, and to-day we have the contented hens that stay quietly in coops and lay eggs all through the year.

Turkeys have never been thoroughly tamed, for they love to wander. We still have wild ducks and geese on many lakes and marshes.

The haunts of the wild animals of the earth are shrinking very rapidly. Hunters and men of science who want skins for museums must go to Africa or South America or Alaska. Photographers who want pictures of wild life for the cinema must go to foreign countries. In the jungles there may still be found elephants, lions, tigers, and leopards, and the fast-disappearing hippopotamus and rhinoceros.

The hundreds of wild animals living to-day are roughly classed in a few interesting groups which have common habits. The apes or monkeys are the highest order of animals, and stand next to man. Some of the gorillas of Africa are nearly as large as a man. They have no tails, and are the only monkeys that stand erect without being taught. The gorilla spends part of its time on the ground, but is very shy and is seldom seen in captivity.

The chimpanzees and orang-outangs are the most intelligent apes. These are Old World monkeys, and most of them are tailless. They are more easily taught than the smaller, long-tailed monkeys of Mexico and South America. The howlers and spider monkeys of this group have prehensile tails with which they grasp branches to support themselves as they swing from bough to bough.

Marmosets and lemurs are harmless little monkeys with long, soft, furry tails in which they wrap themselves when sleeping. They are as gentle as rabbits, and not much more intelligent. Monkeys carry their young on their backs or in their arms, and they do so many half-human things that they are credited with more intelligence than they really possess.

The cat family embraces the lion, the tiger, and the leopard of the Old World; the jaguar, cougar, lynx, and ocelot of America. These are all flesh-eating animals.

They have sly, stealthy habits, creeping through the brush and leaping upon their prey from above or behind. All are more or less afraid of man, but they are easily trapped. They have powerful jaws, sharp teeth, and terrible claws with which to tear their victims.

The jaguar is the South American tiger. It has spots somewhat like the leopard, but it is a larger beast with a big head, short tail, and black rosettes on its golden-yellow hide. It kills pigs and cattle and even horses and deer, but is afraid of man.

The cougar is found in the Rocky Mountains, and is a thin-bodied, flat-sided animal that hides in the daytime and hunts at night. The bobcat is a common short-tailed, tree-climbing lynx. The Canadian lynx is larger. The lynx catches chickens, rabbits, and other small animals, but is a treacherous fellow and cannot be trusted even when captured and tamed.

The dog family includes wolves, coyotes, and foxes. All these animals have mean, sneaking traits. They frequently hunt in packs, and kill animals much larger than themselves. They are seldom trapped, and the coyote is said to be so wise that he knows when a man has a gun. The wolf is a cruel beast that eats his own brothers if they are wounded.

The marten family includes weasels, otters, minks, ferrets, and skunks. These are small, flesh-eating

animals. The wolverine and the badger are larger animals belonging to this group. The wolverine is about the size of a large dog and is the hungriest member of the family. If a wolverine gets into a camp it will destroy everything, whether it can eat it or not.

The bear family ranges from the white polar bear of the cold regions to the grizzly, the big brown bear, and the small black bear. The racoon is called the "little brother to the bear." The black bear climbs trees, but the grizzly lives on the ground. In the colder regions bears hibernate, that is to say, they sleep all through the winter months. They find a den in the rocks or in a hollow log, and remain there, wrapped in slumber, until the spring.

Several other smaller animals also hibernate. The squirrel comes out on sunny days and eats from its store of nuts, but the woodchuck and racoon sleep all the winter. The heavy sleeper, such as the hedgehog, chooses a hole as soon as winter comes, rolls himself into a tight ball, and goes to sleep for the entire season. Since he does not move, he does not rapidly use up his reserve fat or energy. Even his breathing is slow, and his heart beats feebly.

Many animals are burrowers. The badger, the woodchuck ,and the anteater burrow in the ground, where they hide their young and are safe from their

enemies. The *gnawing* animals are called *rodents*, from the Latin verb *rodere*, 'to gnaw.'

The shrews and moles are little mouselike fellows that are seldom seen above ground. In farming countries underneath the long dead grass which covers the top soil, cutworms and wireworms deposit their larvæ. Here little moles police the ground. The mole is a furry little beast with no neck and no external ears or eyes. He looks like a short-tailed mouse. The shrew has a neck and external ears. Since moles seldom see daylight, their vision is very dim.

Bats are strange, wing-handed creatures found among the caves and rocks. They fly about at night, and in the daytime hang head downward from the roofs of dark caves.

The squirrel families range from the big grey squirrel of the tree-tops and the smaller red squirrel to the tiny ground squirrels and rock squirrels that live on nuts and roots.

Among the hoofed animals of the wild are the deer—swift-footed, shy creatures—the reindeer and the elk with their wide-spreading horns, the antelope, and the mule deer. The giraffe is found in Africa. Its long neck allows it to browse in the tree-tops. In South America is the tapir with its hog-like body, and in Mexico the peccary, which is a sort of wild hog. All are browsing beasts living on grass and herbage.

In South America, Africa, and Australia are found the anteaters. They are toothless mammals that root up the earth with their long snouts and feed upon ants, which they lap up with long, sticky tongues. The giant anteater is the largest of these. Among them is the armadillo with his bony shell, into which he disappears like a turtle and rolls away from his enemies. The slowest-moving animal in the jungle is the sloth. It hangs to the limbs of trees and is easily knocked off and killed with a stick, for it offers no resistance.

A curious and clever member of the rodent family is the soft-furred, broad-tailed, bright-eyed beaver. , At one time this animal was found in large numbers in Europe, and when the Romans reached the place where London now stands there were many beavers in the Thames Estuary. Now, however, there are few in Europe, and their quaint habits can best be studied in North America.

A fully-grown beaver is three and a half feet in length, and covered with a warm coat, the outer surface of which is chestnut-brown and the inner, next the skin, a lighter and more greyish tint. The beaver is amphibious, as you would guess if you saw his webbed hind-feet, and he makes his home among willows and other water-loving trees, near to running water. He is not a lover of solitude, but settles in colonies with others of his family, and there they all work, and plan, and

build, with an intelligence and a resourcefulness that would be creditable to that much larger animal, man.

The beaver builds dams to raise the level of the water in what we may call his 'home stream,' using branches of trees, mud, and stones, and carefully calculating the size and position of the structure, which is usually about twelve feet thick at the base and narrows to a breadth of only two feet on the top. If the stream be a gentle one the dam will be practically straight, but when the current is powerful the beavers give their dam a curve inward toward the running water. With the aid of its exceedingly powerful teeth the furry builder can gnaw through tree-trunks as much as eighteen inches in diameter. When the tree falls he strips off the branches, and divides the trunk into logs of various lengths for use as building-material. The bark he peels off, and stores in his larder against the coming of winter.

But this amazing little beast is not only an engineer. He builds houses, too. Each of these houses, or 'lodges,' will hold a family of six or seven. The walls are very thick, made of mud, moss, and timber, and roofed in by a layer of mud renewed every year, and plastered with marvellous smoothness. Formerly it was thought that the beaver used his broad tail as a trowel, but it has now been proved that it is simply a rudder to steer him when swimming, and that in his

labours as mason and plasterer his only tools are his clever forepaws.

The pouched animals are the kangaroo and opossum. The young are very small when born and are carried in a pouch under the mother's body until well grown. The kangaroo snatches up her baby, pokes him into the pouch, and runs away with great leaps on her strong hind-legs. If the danger becomes too great and she is likely to be overtaken, she sometimes throws the youngster into the grass and runs on alone.

Two strange, egg-laying animals of Australia are the duckbill and echidna. The duckbill has a bill and feet like a duck, a body like a mole, and like a turtle lays soft-shelled eggs in a burrow in the ground. While its nest is on land, it lives and eats in the water.

The elephant is the largest land animal and the only one with a trunk. It is found in India and Africa. The end of the trunk acts as a sensitive finger-tip, picking up very small things and carrying food to the elephant's mouth. The rhinoceros and hippopotamus are other huge beasts. They have the same dark, thick, hairless hide as the elephant and both are herb-eaters, but the hippopotamus lives chiefly in the water. The rhinoceros has a horn on his nose; some of them have two horns.

Rabbits and hares are found the world over, varying

from the powerful jack rabbit to the gentle 'bunny,' beloved of the children.

Many of the wild animals prowl at night and sleep hidden away in the daytime. Even in cities small animals creep about in gardens or through deserted buildings at nights. Rats and mice, weasels and ferrets, squirrels and rabbits, are our close neighbours. Hundreds of species of insects, worms, and reptiles are on the land. Living creatures are all about us, dependent upon us for their lives.

Man must constantly fight to prevent the animal and insect world from taking his crops; for the birds steal fruit, mice eat grain, and foxes rob the hen-roosts of the farmers. On the whole, however, he receives more help than harm from his four-footed friends, and to-day the study of animal life is one of the most interesting chapters in the book of Nature.

CHAPTER XIII

THE STORY OF BIRDS

NEXT to the green trees, and the kindly fruits of the Earth, and the friendly animals we have tamed, we must give a place in our hearts to the winged hosts of the air. Many birds are most truly our friends. They delight us with their songs, they guard our gardens from the onslaughts of creeping and flying insects, they are our companions and—very often—our pets.

We may travel far and wide, and yet never reach a place where no birds are to be found. Of course, not all birds are pretty and gentle, not all birds sing. Among the mountains we meet the fierce eagle, the cruel vulture, the keen-eyed hawk. In cold regions behold the comical penguin; in hot and sandy surroundings the long-legged ostrich; in jungles the gaily-hued parrot; among ruins the solemn owl.

Man early learned to make use of his neighbours the birds. In Peru whole garments were wrought of coloured feathers. In Europe, in the Middle Ages, arrows were winged with goose-quills, and the helmets of the warriors were adorned with the plumage of the ostrich, the peacock, and the heron.

Man has learned to take the feathers of our domestic

birds without taking their lives. He has taught them to produce eggs the year round for food. But best of all, he has learned to protect the wild birds, since he has discovered how much they benefit him by eating millions of insects which would destroy crops of fruit and grain.

There was a time not long ago when we studied birds by making a collection of their eggs and of their skins. Then we found that we were destroying life to no purpose; for of what use is a stuffed bird or an empty eggshell except as a specimen in a museum?

For years the Audubon societies have been working to protect bird life. Now we know that we may study birds much better with a camera than with a snare, and far better with a field-glass than with a gun.

With very little effort a person may become familiar with forty birds and their habits; while real attention to the subject will give him, we are told, the power to identify a hundred and twenty-five birds, and will put him in the class of real bird students, or 'ornithologists.'

In the Temperate and Torrid Zones are the perchers, or birds who live in trees. They are our loveliest songsters and our most active workers and helpers. In the Torrid Zone are many brilliant-coloured birds. Most of them have coarse voices and are lazy because an abundance of food is always at hand.

In the Temperate Zones are the smaller birds of

plainer plumage. Among them are a few bright-hued songsters: the wild golden canary; bright blue beauties like the bluebird, the bunting, and the jay; the brilliant-hued scarlet tanager, the gaudy cardinal, and bright-dappled woodpeckers. But the greater number of the songsters have neutral colours of brown and olive-green that help them to hide from their enemies.

These birds of the middle zones have tuneful voices. We all know the cheering lilt of the robin and the flute-like notes of the thrushes and larks. We marvel at the variety in the songs of the cuckoo, linnet, the nightingale, and the various members of the finch family. From early morning till the sun goes down we can hear the varying chirrup and musical notes of other songsters. They keep us in good cheer while they are eating caterpillars, insects, weed seeds, and even some of the small animals that threaten our crops.

Birds need a great deal of food because they are so active. They eat all the time they are not sleeping or caring for their young. This alone would prove that the farmers do well to protect the birds.

Naturalists and scientists agree that life on this planet would be impossible without the protection afforded us by the birds which destroy winged pests, bugs, worms, larvæ, and lice.

The golden eagle catches in its talons mice, rats, and

rabbits, and skins them for its young; but as soon as the baby eagles can leave the nest they are taught to kill their prey. The bald eagle and osprey are fishing birds. Hawks and owls kill grasshoppers, mice, and moles.

The gannet lives on fish. It soars to a great height, then drops to the water like a plummet, stabbing with its long, straight beak the fish swimming near the surface. The pelican lives on the coast and fills his great pouch with fish. Pelicans are said to form in a line and wade through shallow water until they have a quantity of fish cornered, when they scoop them up with their great beaks and store them in their throat pouches. They also fly above the water, darting down with a great splash for their prey.

The cormorant fishes in a different manner. It pursues its prey under water, turning and twisting about until it seizes the fish with its hooked beak. Then it comes to the surface, tosses the fish into the air, catches it again as it falls, and swallows it. The Chinese train cormorants to fish for them. They tie a collar round the birds' necks so that they cannot swallow their prizes.

The bird has nothing to take the place of a hand unless it is his beak. The parrot has a sharp, curved beak that will bite wood and crack hard nutshells. The kingfisher's beak breaks the bones of the fish, and the seed-eaters crush the hardest seeds with their sharp-edged bills. The humming-birds reach into the

hearts of the flowers with their long beaks. Storks and cranes use their beaks to fish in the mud for frogs and reptiles.

Every bird has feathers, and nothing that is not a bird can show any trace of them. The whole body of the bird is fitted to the habit of flying. We have long envied the bird his power to fly. In fact it was the birds that taught us to build our aeroplanes after the shape of their wings and bodies. The birds' wings serve as planes and propellers, for they have both lifting and driving power. The tail is the rudder and helps to steer. It also acts as a brake when the bird alights. Some birds, like the birds of prey, soar and remain in the air a long time with motionless wings. They can sail in a spiral to a great height. Others dart like swallows. Some birds walk on the ground, while others hop.

Birds, like aviators, can attain a certain speed in the body of air in which they fly, but we must remember that their speed measured from the ground may be far different. There is a 'ground speed' and an 'air speed.' A bird may be flying fifty miles per hour in a twenty-mile-per-hour wind. It might seem from the ground to be going seventy miles per hour or only thirty miles per hour, depending on whether it is flying with the wind or against it. In either case its 'air speed' remains fifty miles per hour.

Aviators have measured the air speed of certain birds, and have found some that can fly one hundred miles an hour. Carrier pigeons have been known to make a mile a minute, while ducks go from forty to fifty-six miles an hour.

Birds have been seen flying three miles high, though they seldom are seen above one mile. Most bird flight is within half a mile of the ground.

Some birds, like the ostrich and emu, are tall with small wings and very long legs. They have never used their wings and have not the power of flight. They use their wings to balance their bodies as they run at great speed across open country. When attacked by enemies they use their legs to kick with great force. The soft, hair-like feathers of the ostrich make the beautiful plumes of commerce.

The penguins have lost the use of their wings except as flippers to help them to make their way in the water. These birds are wonderful swimmers and dive under the water like seals. They go hundreds of miles over the trackless sea of the South to rear their young. There, in the snow and ice, they are perfectly at home.

Most birds cannot brave cold weather, but migrate to warmer climes to spend the winter. In the spring they return to their old haunts. These long journeys are possible because the bird has a sense of direction that shows it the way. A tiny humming-bird flies

hundreds of miles through the air with nothing to guide it but this homing instinct. Birds' legs have sometimes been marked with aluminium rings, and many facts of bird migration have been proved by observing birds so marked. It is certain that some return year after year to the same neighbourhood and sometimes to the same nest. Birds have been taken from their nests and carried in cages hundreds of miles away from regions where they live, and they have returned.

The beautiful tanager that nests in the spruces of North America in the summer spends his winter in South America. In the autumn we hear the squawk of wild geese and see the leader going straight south toward the warmer waters. Before they start there is a battle on the pond to see which gander should lead the flock. Who has not seen and heard the "gathering swallows twitter in the skies," before they set off on their long flight to the warm lands of the golden South?

The carrier pigeon gives the best example of the homing instinct. When it is far from home it flies, like the bee, high in the air and returns to its nest in the most direct line possible.

Birds are wonderful weavers. A study of their nests fills us with admiration. The oriole hangs her nest from the swaying branches, but it is fastened so securely that the wind seldom tears it loose. The chimney-swift cements its home firmly to the side of

the chimney with mud. The humming-bird makes a tiny cup of a nest with cobwebs, down, and the saliva from her own mouth. The kingfisher digs a tunnel for its nest.

The nests are so carefully hidden and guarded that we must hunt well for them. Only a few confiding birds nest under our very eyes. Hundreds of sticks and grasses are gathered for a simple nest. Some birds make several nests in a summer and rear two or three broods of young.

By learning a dozen new birds each spring, we may make ourselves not only bird students, but their protectors; for no one who watches these little creatures can overcome the desire to guard them.

CHAPTER XIV

PLANTS AND A PLANT WIZARD

SINCE men and animals live largely on plants, and farmers are kept busy growing crops to feed the world, we want to know more about how plants grow and produce seed. We may easily see what the animals about us eat and drink, but it is not so easy to learn just how plants eat and grow and bear fruit.

Plants need food, water, and air just as animals do. They also need warmth and light. The plant has different parts—a stem, roots, leaves, and flowers. It divides its work among these parts. The roots of the plants have their work, and it is different from that of the stem and leaves.

Let us first look at the roots. Pull up a radish from the garden, and you notice that the upper part of the tap root is large and round; it is stored full of food. It grows smaller and smaller toward the end. All along this tap root are tiny rootlets, with root-hairs branching off from them. These root-hairs cover only the tips of the smallest rootlets, but they extend out in all directions. They are very close together, for often there are as many as thirty thousand to one square inch. They are not young roots, because they

never grow larger. They are only tiny little hollow tubes which contain sap. They have no pores or holes for water to enter, but it easily soaks through their thin walls. Thus these root-hairs drink in the soil water which contains many of the plant foods, and the sap carries this watery food up along the larger roots and stem to the leaves. Here the sunshine helps to make the plant food ready to build up the stem, leaves, and the fruit of the plant.

The larger roots do not take plant food from the soil. Their work is to hold the plant firmly in its place in spite of storms and heavy rains. When a plant is taken up to be transplanted, most of the small rootlets with their many long hairs are broken off. Perhaps you can now understand why a plant is so likely to wither when it is transplanted.

The stem, or trunk, of the plant bears the leaves and holds them up in the air and sunshine. It carries the watery plant foods from the roots up through the outer wood layer to the leaves. The food materials, or starch and sugar from the leaves, pass down under the bark to the part where they are needed to enlarge the plant.

But more interesting than the roots or stem are the leaves. They serve as so many stomachs where the plant food is digested and made ready for use. The chief work of the leaves is to change the plant foods

into starch and sugar. They take carbon dioxide from the air and combine it with the other food which comes to the leaves through the root-hairs, forming starch and sugar. The leaves also give off to the air all the water that is not needed by the plants. If the leaves, as they often do on very hot days, give off more moisture than the roots supply, the plant withers—the leaves droop—in order to prevent further evaporation.

The starch and sugar made by the leaves is either stored up for food or used at once to build plant tissue. When enough has been stored the plant begins to flower. The flower is sometimes beautiful, like the apple blossom, but often, as in wheat or oats, it is not showy.

The flower of the plants has a very important work to do, because it contains the parts which create the fruit. The fruit contains the seeds from which new plants may be grown. If the flower fails to do its work there will be no fruit, no seeds, and no new plant, unless a new plant can be started from a slip or cutting of the old plant.

The flowers of different plants differ very much, but they usually have two parts. One is the 'pistil,' or mother part, which contains the ovule, or seed germ. This ovule will not grow into seed unless it receives some pollen or yellow dust that grows on another part called the 'stamen.' The seed itself contains a germ,

a tiny baby plant, all tucked under a good cover with food enough for it to live on until it can send out rootlets into the ground.

Every plant must have its flowers with their stamens and pistils, but the stamens and pistils are not always together in the same flower. Examine a cornstalk as it grows. The tassel is the stamen, with its yellow dust, or pollen; and the ear is the pistil. If the pollen does not fall from the tassel on the silks of the ear, and thus fertilize the ear, there will not be a grain of corn on the cob.

The corn is only one of many plants that have their male and female flowers separate. Such plants depend partly upon the wind to carry the pollen from the flower to the pistil, where the new seed is to grow. Some plants depend upon insects to carry the pollen for them. These plants have bright-coloured flowers that the insects can easily see. They also secrete a sweet food, or nectar, to reward the insects for their trouble. They hold out bright red and yellow and blue petals, and say to the insects, "Here you can get good honey."

Some plants depend upon insects that fly only at night to carry their pollen. These plants have not bright flowers, because colours cannot be distinguished in the darkness. They have white flowers; and to aid the insects in finding them, they have a strong, sweet

odour. The insects come from far and near for the sweets. They brush against the stamens and get covered with yellow pollen dust. Away they go to other flowers, leaving some of this pollen on every plant they touch. When they go in deep for the honey they leave pollen on the pistil just where it is needed.

Plants bear the strongest and best fruit and seed when the pollen has been brought to them from another plant. In a cornfield the ears on one stalk may receive pollen from their own tassel and from a dozen others standing near. Sometimes when a farmer wants corn for seed he goes about a certain part of his cornfield and cuts off the tassels of all the poor stalks. In this way he allows the ears to receive pollen from only the strongest plants.

There are thousands of different kinds of plants in the world. Perhaps there was a time when there were very few plants. But as they spread over the Earth they found different kinds of homes. Some seeds were gradually carried into cold regions, and others into hot places; some found wet spots, and others came into desert regions. Some found homes on high, rough mountain-tops where the storms raged about them, while others fell into low, shady nooks where they were protected.

As the plants were slowly carried into such different kinds of homes, they kept fighting for life and food.

Often many plants were struggling for air and sunshine on the same little spot; and only those that proved good fighters lived. Slowly but surely many of these plants changed to meet their new surroundings and became unlike their early parents and even unlike their close kin. Each one set to work to protect itself and get its own food, and thus it slowly developed new parts, new ways of growing, and new ways of fighting for food. Only the strongest plants lived to spread their seed. In this way the world came to be covered with multitudes of different plants.

It is interesting to study the habits of different plants and how they grow and spread their kind. One of the important things that the farmer wishes to know about them is how they scatter their seed, because many weeds grow and fight for life where the farmer does not want them.

Some plants, like the coconut, grow their seed in a hard shell which is waterproof, so that they can float on streams and rivers to new homes. The seeds of the sycamore and the ash have wings, and on these they sail away across the fields wherever the wind will carry them. The dandelion seed has a queer little balloon by which the wind carries it to some far-away home. Then we know the burdocks and other burrs that catch in our clothes, or fasten themselves on passing animals and hold tight for a long ride, to fall at last and begin to

grow in a new region. Any boy or girl who will examine the seeds of plants and do a little thinking will discover many interesting and wonderful secrets about their different habits.

Man has chosen certain plants that furnish food for him and his flocks, and these he tries to help to good homes where they will grow and bring forth their harvest of grain or fruit. He spreads and sows these plants in different ways. He sows the seed of the common grains or cereals and covers them with earth. Sweet potatoes are grown from slips or plants; other potatoes from the 'eyes' of the potato; grape-vines from cuttings or twigs clipped from the vine. Sugar-cane is grown by planting a short piece of the stalk.

Many plants do not grow well from seed, and man has learned to grow them by grafting or budding. A bud or graft twig is taken from one plant and so carefully put upon another of the same family that it will grow as part of the plant. And the strange thing about it is that it will produce its own kind of fruit, and not the kind of fruit of the plant on which it is grafted.

Some plants, such as the epiphytal orchids, have no roots in the earth, but grow upon other and bigger plants, attached to them by suckers. Others, such as the sundew, actually catch and devour small insects.

Science has taught man to alter the forms and colours

of flowers at will, and to work marvels among them; but there will always be some old-fashioned people who will think the old-fashioned flowers the most beautiful of all.

Luther Burbank is well known to the world as the 'plant wizard.' He was his father's thirteenth child and was born on a farm in Massachusetts on 7th March, 1849. His mother was very fond of flowers. Though the cares of a large family kept her very busy she always saw to it that her home was surrounded with blossoms.

Luther, as a very small child, loved flowers. His sisters said they could always quiet him when he was a baby by putting a flower in his hand. He grew up a frail, shy lad. He was afraid of strangers, but interested in all they had to say. In the busy world in which his family lived Luther learned to use the saw and hammer, as well as to till the soil. He read the best books and studied a great deal.

When he was quite a young man he had sunstroke, which affected his health for a time. He studied medicine for a year, and the acquaintance with biology which his study gave him was a great help to him afterward in his work with plants. About this time his father died, and he had to give up his medical studies; so he decided to become a nurseryman and to grow young trees for the farmers' orchards.

Burbank read Darwin's book, *Animals and Plants under Domestication*, and began to improve his vegetables and seeds. He found a way to raise sweet corn for market earlier than anyone else, and he developed a new kind of potato called the "Burbank" potato. The rights in this he sold to a wealthy man.

Two of his brothers had gone to California, and Burbank knew that if he wanted to work at developing new plants all the year round this was the place to which he should go. He therefore sold his little farm in Massachusetts and started across the continent with very little money but a great deal of ambition. It took him many days to cross the country. When he reached California he had only a few books, a little clothing, and ten Burbank potatoes.

The first year in California Burbank barely made a living. He worked as a carpenter, and helped in a greenhouse. He became ill from the dampness of the greenhouse, and was unable to work for some time. It was five years before he had enough money to do the thing he had set out to do. Then with only a thousand dollars he started his nursery.

In 1881 a wealthy banker of San Francisco asked him if he could have twenty thousand plum-trees ready to plant that autumn. At first Burbank thought it would be impossible, but he knew this was a great opportunity; so he said he would try.

He knew that almond seedlings would grow much faster than plums, so he decided to grow the almonds and graft plums to them. He planted the almond seeds in coarse sand, and by June the plum seedling buds were ready to graft. In order not to kill the almond seedlings he let the young tops die very gradually after the grafting was done. By December 1st he had almost the required number of young trees—enough to satisfy his customer; but, best of all, he had made a name for himself as a nurseryman.

In good time Burbank's nursery was making money enough to support itself, so that he had his own time to experiment. Then began the development of the many new fruits, vegetables, and flowers that he has produced for the world.

We can tell of only a few of the things he has done; but these will give you an idea of how new plants are produced, and of some of the remarkable aspects of plant life which he made use of in his experiments.

We have learned that every perfect flower has petals, stamens, and a pistil. It also has sepals, which are the outer leaves of the blossom. They are usually green, but not always so. The bright-coloured parts of the flower are the petals. Inside are the stamens, each of which bears on its stalk a little box of yellow powder, called the pollen.

At the heart of the blossom is the pistil, where the baby plant is to grow, and on the top of the pistil is the stigma. When the pollen falls upon the stigma it fertilizes or gives life to the baby seed which grows in the pistil. No seed will develop in the flower unless the stigma receives the pollen.

We know that bees of one kind or another are the great distributors of pollen in orchards and gardens. The fruit-trees put forth their blossoms, which have perfume to attract the bees. Scientists do not agree as to whether it is the colour or the scent that attracts the bee, but we know that the bee flies many miles in a straight line from his hive to the flowers. We are inclined to think he must have a very fine sense of smell as well as a sixth sense, the sense of direction. There is no question that the colour of the flower also attracts the bee.

"I should think the bees buzzing round from one flower to another would mix everything up," said some one. "Daisies would be crossed with poppies, and carnations with geraniums."

"But the bee is a wise harvester," is the answer. "If he sets forth to make clover honey in the morning he gathers nothing but clover nectar all day. He goes from flower to flower, but always to flowers of the same kind."

While some flowers attract bees, others attract

butterflies and humming-birds. Plants with deep flowers like those of the honeysuckle give up their nectar only to birds or insects with long beaks.

Some flowers can be crossed with those of a different kind, but there are many blossoms which cannot be intercrossed. There are different reasons for this. The pollen grains of some flowers are too large to reach the pistils of others. Many plants bloom at different times. The stamens of some flowers open earlier than the pistils, and when the bee has sucked the honey and taken the pollen to other flowers, then the pistil opens and he returns to bring the pollen from another flower of the same kind to pollinate the first one.

If a white daisy is pollinated by a yellow daisy the new blossoms will not be the same, but if it receives pollen from a white daisy the seed will reproduce white flowers. When the white and yellow flowers are mixed we say the flowers are crossed, and in time some of the flowers will be white and some yellow, or perhaps they will be white mixed with yellow.

Burbank worked a great deal at cross-fertilization. He took a fruit blossom and a fine sharp knife. On his watch crystal he gathered the pollen from a blossom. He cut away the petals and the anthers of the flower he wished to pollinate, so that the bees would not be called to it to undo his work. Then he carefully shook some of the pollen on the stigma of the flower he wished

to fertilize. He put a label on this blossom and watched it carefully. The seeds from it he would plant the next season and cross-fertilize again. It may take many years to grow the plant or flower that has just the qualities desired.

At his farm at Santa Rosa, California, Burbank worked steadily until his death in 1926. Besides the bees he had many other helpers. Workmen were always busy preparing the soil, planting and trimming and spraying to kill pests. Precious seed-pods were protected by having paper sacks tied over them. There might be more than two thousand new experiments going on all at once.

Burbank would tie a white string round the stem of the plant which had a quality he was anxious to preserve. Sometimes he fixed a stake with a double cross marked on it, which was his 'O.K.' sign.

When the fruit ripened he was very busy. It was photographed, and a complete written record of all its qualities was made to compare with its record of the year before to see what progress it had made.

This wonderful care and this patient experimenting has produced some things that seem miraculous. Burbank has taken the seeds from the grape, the stones from the plum, the thorns from the blackberry, and the spines from the cactus. He has changed the colour of

the calla lily and of the poppy. He has given fragrance to flowers that had none before. Besides creating new fruits, he has greatly improved the size, flavour, and bearing qualities of other fruits and vegetables in wide use to-day.

CHAPTER XV

ABOUT FORESTS

THERE are many beautiful trees in the world, most of which are good friends of man. If you think for a moment you will realize that a great deal of the character of a country is suggested by its trees. Thus palms make us dream of Egypt, and the Indies, and the isles of the South Seas, oaks are proverbially English, conifers, that is, trees bearings cones, such as the fir, the pine, and the larch, summon up visions of cold countries, Scotland, Sweden, Canada.

The word 'forest' did not always mean a large tract of land closely set with trees, which is the meaning it has for everybody to-day. In Anglo-Norman England, under the Conqueror and his sons, a 'forest' was simply an area set apart for hunting or other sport, and might have been open heath or moorland, with few trees, or none, to be seen. Before very long, however, the word acquired its present meaning. A great part of the British Isles was then covered with dense woods, woods whose knotted and tangled trees had never felt the woodman's axe, and whose dark depths had never been trodden by the foot of man. Now forests have become so scarce, it is necessary to plant them, in case

England should some day be denuded of trees, and all the timber we used for household and industrial purposes be obtainable only from abroad. In 1903 it was estimated that about twenty-one million acres of waste, heath, and rough pasture in the United Kingdom were suitable for afforestation.

At first it seems as if a forest *must* be natural, and not artificial, but as a matter of fact the art of forestry is a complicated and highly developed one, and people who have mastered it know how to plan vast plantations, and to make them flourish. Sometimes a new forest may be planted on the top of an old one which has fallen into decay. Then it is necessary to fell the decrepit trees, blast the roots that have struck deep into the earth, and clear away the choking undergrowth. There are two ways in which a growth of new trees may be begun—by sowing seed and by planting saplings or slips. Mice and rabbits do all they can to prevent the seeds sprouting, and where these tiresome little fellows are numerous it is better to choose the alternative method. Small trees should be planted at the rate of five or six thousand to each acre. In moist soil, such as peat, moss, or moor, spruce-fir, willow, poplar, alder, and birch will thrive; in sandy soil, without streaks of gravel or clay, silver pines, sycamores, sweet chestnuts, and wych-elms will flourish.

At one time the coppice, or underwood, of the forest

was quite a valuable commodity, as it was used for fences, garden furniture, sheep-pens and hop-poles. But the introduction of wire and bamboo for these and similar purposes has altered all that, and it is the mature timber that has most value now.

The most thickly wooded area in Europe is Bosnia, where 53 per cent. of the total area is covered with forests; the jungles of India fill 114,000 square miles; Canada is 40 per cent. forest, and her great neighbour, the United States, 37 per cent.

Of all the trees that grow in England—and many very beautiful trees grow there—few are more admired and none is more truly English than the oak—*Quercus robur*, to give it its botanical name. It lives to a tremendous old age—some are alive now that were saplings when the Normans landed at Pevensey—and it attains a tremendous girth. The famous oak of Thoresby extends its shaggy branches over one hundred and eighty feet of ground, and can give shelter to a thousand horsemen! The wood of the oak has a beautiful grain and takes a fine polish. It is especially suitable for carving, and every one has seen, at one time or another, some exquisite examples of the old-time woodcarver's skill in oak. The passing of years gives to this wood a rich, dusky tint which modern furniture-makers do their best to imitate with the aid of chemical stains and varnishes.

When Julius Cæsar paid his fleeting visit to the isle of Britain he noted with surprise that he saw no beech-trees there. But the fact that the greatest of all the ancient Romans did not *see* them did not mean that there *were* none, for the beech is a native of Britain. It is one of the most beautiful of trees, with its high, smooth, silver-grey trunk and its shimmering silken leaves of delicate green. Thrushes and pigeons, squirrels and field-mice, greatly enjoy a banquet of beech-nuts. But have you ever noticed that the great grey trunks of the beeches rise stark and unhidden from the earth where their scattered nuts and their russet leaves are strewn? No other trees nestle near them, no shrubs or saplings huddle round. "How most other plants hate the beech and the ash!" wrote Lord Redesdale. "How resolutely they refuse to grow under their shade!" Certain laurels are among the few exceptions to this curious rule.

The pine-tree is the sailor's tree; its wood being very straight, and having a quality which boring insects do not like, is especially suitable for a ship's timbers, masts, and spars. The sycamore is dear to children because of the quaint little 'aeroplanes' which carry its seeds when its drooping clusters of greenish flowers have withered. Its wood is used to make violins and violoncellos, reels, bobbins, and printers' type. Though the elm is one of the most familiar trees in the British

Isles, it is not really an English-born tree, as it was brought hither by our old friends the Romans. You can recognize an elm at once by its rough bark and its small, serrated, or saw-edged, leaves. Pear-wood, holly-wood, and the wood of the tulip-tree were used with excellent results by the famous French and English cabinet-makers of the eighteenth century, inlaid in furniture made of harder and tougher woods, such as mahogany, walnut, and oak.

When you stand beneath the shadow of some mighty tree, and lift your eyes from its massy trunk to its fluttering canopy of leaves, your first thought will be that the trunk is the father—or even the ancestor—and they are his children, his descendants. Yet that is not scientifically true. If the woodman should come along with his ringing, swinging axe and fell one of the forest trees, you would see, if you looked closely at the severed trunk, that it is formed of many rings, each within each, from the outer bark to the inmost core. Look closer yet, and you will notice that these rings in turn are formed of fine fibres, slight and delicate in themselves, which, when welded tightly together by the processes of growth, make the fabric, the substance, of the solid wood. Every fibre is the legacy of a dead leaf, a leaf that fluttered to the ground long ago. It is by the downward thrusting of such fibres from the leaves that the tree lives, and grows, and gains height and girth as

the years pass. Thus, in a sense, the tree is the child, and not the father, of its numberless leaves.

There are many products from the wild trees as well as from those we have cultivated, for all our wonderful fruit-trees and orchards came at one time from the forest. South America has a cow-tree that has a white, thick sap like cream. Rubber is made from a tropical tree whose gum supplies our motor-car tires. The maple-tree, with the foliage that turns to brilliant colours in the autumn, supplies a sap that is boiled into sugar. The southern pine furnishes turpentine and resin.

In the warmer zones are varieties of palms, including the date and the coconut-palm and the eucalyptus-trees, that lose their bark instead of their leaves. There are also many flowering trees, like the magnolia, the hibiscus, and acacia.

In the jungles of South America and Africa the trees crowd so close that they have few branches, but reach upward toward the light. They are loaded with moss and vines. Here magnificent hardwoods, like mahogany, ebony, rosewood, and sandalwood, decay far from transportation and the service of man.

Only the Eskimo and the men of the very cold regions have learned to live without wood. Civilized man has always had growing close at hand plenty of timber for fuel and for shelter.

Forests also have an influence on the climate of a region. Much of the rain that falls beneath the trees dissolves plant food from the soil. This is taken up by the roots of plants and trees and carried upward to the leaves. The trees and plants absorb all the food and much of the water, but the rest of the water is breathed out through the leaves into the air. This gives to the air over the forests a coolness which is felt by balloonists and aviators three thousand feet above the earth. Thus we see that forests in a region often make the climate cooler.

Forests are also known to increase the rainfall of a country. Rain is caused by the cooling of the vapour in the air. The cool air over the forest chills the passing moisture and causes it to fall as rain. Experiments carried on for thirty-three years in a forest of eighteen thousand acres in France show that for every thirty-six inches of rainfall in the centre of the forest there were only thirty inches at the edge of the woods and twenty-four inches in the open field ten miles away.

Forests on steep slopes help to prevent floods. Beneath the trees of the forest is a thick covering of leaves and twigs which rests upon a very porous mould that takes up water like a sponge. This water is held and allowed to escape very slowly. It then passes along

underground and reaches the streams very gradually through seepage and springs.

The experience of other countries also proves that forests prevent floods. In Italy the Appenines have been stripped of their forests; the result has been marked floods of the river Po. This has led the Italian Government to replant nearly a million acres. In Austria the forests have been cut from many of the mountains, with the result that great floods have occurred on the Tyrol. To prevent these floods the Government began before the war to replace the forests along a hundred streams.

In the United States where the hills and valleys have been deforested serious floods occur, while other regions that are forest-covered give off a more even flow. For example, the north fork of the Yuba River of California is forest-covered, while the south fork has had its forests cut. The former has a river basin of 139 square miles and the latter one of 120 square miles. The first never has less than 113 cubic feet of water a second running through it, while the second for four months of the year has practically no water.

The replanting of forests is now going on in almost every country in the world. In France, not only the headwaters of the Rhone and Seine have been replanted since the forests were cut down, but the sand-dunes have been treated in the same way. In some

European countries it is against the law to cut a tree unless another is immediately planted to take its place.

Let us see how the wood that is cut every year is used.

It is said that twenty times as much timber is sawed into lumber as is used in any other way. Most of this lumber is used for building wooden houses, barns, and sheds, while still more is used for doors, windows, and inside furnishings of brick and stone houses. Then much selected lumber is used for furniture, wagons, ploughs, harvesters, and other tools. We use lumber for the making of cars, railway sleepers, barrels, pit-props, boxes, crates, clothes-pegs, spools, and matches. Some of it is ground into pulp to be used in making paper for our books and for other purposes. Some of the more expensive woods are used for veneer. Thin sheets are cut into small strips and glued to cheaper woods as a finish for furniture. The bark of some trees is used in tanning leather.

Turpentine and resin are produced from the sap of certain growing trees. Tapping trees need not destroy the growing forests any more than tapping maple-trees destroys them, but the method formerly in use was destructive. The trees were 'boxed'; that is, cuts five or six inches deep and several inches long were made in the trunks. New methods of getting the

sap have been devised with the result that the trees last five times as long and yield a third more sap each year.

Of all the wood that is cut fully two-thirds is wasted in the forests. It is left to decay or it is burned.

There is also much waste in converting the logs into lumber. Some of this waste is due to the use of very thick saws which cut away too much wood in sawdust. Then it is the habit of the lumber trade to limit the length of the sizes of lumber sold, and shorter lengths are thrown away. These shorter lengths could often be used, and they could be sold at a lower rate than the standard lengths. The pieces which are too small for short boards could be used for matches, wooden baskets, or toys. As it is, some of the largest and best trees are now being used for matches.

We are told that out of every eight thousand feet of timber that is cut down two thousand feet are lost in the forest and never reach the sawmill. Two thousand feet more are lost in sawdust, short lengths, and the like at the mill, leaving only four thousand feet to be sent to the factory as lumber. In the factory one thousand feet more are lost, so that less than half is left to be used in the making of furniture. This great waste is unnecessary.

Fire, it is said, has ruined more timber than has been cut by man in the United States since the dis-

covery of America. It is reported that fifty million acres of woodland are burned over every year. This doubtless includes lands in which the standing timber is not destroyed, but the small saplings are killed, and thus the hope of future growth is gone; but it also includes fifteen million acres where the standing timber is totally ruined. This means forty thousand acres every day in the year.

What are the causes of forest fires? In the first place the *débris* that will burn in the woods includes dry leaves, twigs, fallen timber, dead trees, and slashings made by timber-cutting. All this *débris* is soon dry and ready to burn. It needs only a spark, and the forest is ablaze. An investigation of some 2503 fires in the Rocky Mountain district in 1907 showed that 641 fires were caused by railway engines, 638 by campers, 458 by lightning, 49 by brush burning, 43 by criminals, 22 by hunters, and 652 from causes unknown.

How can these fires be prevented, or at least controlled? In one country in Europe the average area burned over yearly is less than one-fiftieth of one per cent. In countries such as the United States and New Zealand where there are vast areas of virgin forest-lands look-outs and patrols are employed, who telephone to others and summon speedy assistance immediately there is an outbreak of fire. The patrol enforces the fire laws among those who travel in the forest.

Forest fires will be fewer when all slashings are burned as the timber is taken out; when all railway engines are equipped with spark-guards; when brush is burned in the rainy season; and when travellers are more careful with camp-fires.

CHAPTER XVI

WATERFALLS AND WATER-POWER

HAVE you ever seen a waterfall? If you live in the British Isles, and have not travelled as far afield as Africa or America, you have probably seen only small torrents, such as those of Tummel, in Perthshire, or Bettws-y-Coed in Wales. These are very pretty, but set beside the great, thundering, gigantic falls of the Zambezi, or of Niagara, they would seem tiny trickles The falls of the Zambezi, said to be one of the most awe-inspiring sights in the world, were discovered by Livingstone, the famous explorer, in 1855, and named after Queen Victoria. They are three hundred and fifty-seven feet deep, and about one mile long. The swift river drops into a deep abyss running from east to west, and the falls are broken into separate cascades by small islets and projecting rocks. At one point, where the sunlight strikes across the long silver veil of spray, there is a gorgeous rainbow all day long. The 'drop' of Niagara Falls is three hundred and twenty-six feet, and the volume of water rushing down is calculated at one million cubic feet an hour.

You would only have to stand near one of these

mighty cascades, listening to its deafening roar and watching its tremendous rush and sweep, in order to realize the meaning of the term 'water-power.' But all rivers represent power, though not all in the same degree. If you think for a minute you will see that every river *must* run slightly *downhill* on its course to the sea, and that as it runs it represents force, or energy. Then you will naturally ask yourself, 'Could that force be turned to any good account? Has it been done already anywhere?' The answer is that it can, that it has, and that with every year that passes, water-power will be more widely and more successfully utilized by man.

It is thirty-six years since the falls of Niagara were harnessed and made to generate electricity, and it will not be long before the Victoria Falls are useful as well as beautiful. A big engineering scheme is now (1927) in progress on the river Shannon in Ireland, and one of the most remarkable recent developments in Italy has been the increasing and very successful application of water-power to industrial purposes. Some hopeful people are declaring that in England the same ends could be attained, and they are even prophesying that within the next ten years or so hundreds of factories will be using water-power instead of steam-power. The effects of this change, if it should ever come about, would be very striking. For one thing, much less coal

would then be required in industry, costs of production would be lowered, and prices would drop without (one hopes) any corresponding drop taking place in the wages of the workers. Another result of the extended use of water-power would be that the air of our great cities would be much purer, and the insides and outsides of the houses much cleaner, because instead of forests of reeking black chimneys there would only be a stray one here and there.

The methods of using and controlling water-power are various, but one of the best known and most successful is the turbine. The name comes from the Latin word *turbo*, meaning 'a whirl'—the same word that lies behind the French *tourbillon*, a 'whirlwind.' In the turbine the water is made to 'whirl' round in a wheel revolving upon a vertical axis, and provided with thin, curved blades. The pressure of the water upon the blades rotates a shaft communicating with a dynamo. There are, of course, different types of turbine, adapted to different necessities and conditions. At Niagara Falls are ten turbines, each able to give five thousand horse-power service to man, and these hard-working pieces of machinery supply power to railways and factories, and light towns by electricity, for over three hundred miles to the east and west of the falls, and for a hundred miles to the north and south.

The term 'water-power' is usually—and correctly—taken to mean that force derived from *running* water; but there are other ways in which the ingenuity of man has caused the speed and the pressure of water to work for him. The principle of the siphon and the force-pump was discovered in Alexandria in the first century B.C. Most lifts are now worked by electricity, but the hydraulic or water-driven lift is still a familiar sight, and is used extensively to carry passengers and loads of all kinds from one floor to another of high buildings.

Yet another—and a very important—aspect of water-power is that represented by the dam. The chief purpose of the dam is to regulate the flow from a great river, to prevent equally floods and water-famines, and to render fertile large tracts of land that would otherwise be dry and bare. One of the most famous dams in the world is that on the Nile, at Assuan, constructed by Sir John Aird. It is 6500 feet in length, 152 feet high, and controls the rise and fall of one of the most famous rivers in the world, a river of which the ancients believed that the source was in Paradise. This dam is built of solid masonry weighing one million tons, and can hold up no less than 70 milliards of cubic feet of water, thereby rendering fertile 600,000 acres of sugar-cane and cotton plantations. A much greater achievement is the huge dam upon the Blue Nile at Sennar,

beyond Khartoum, in the Sudan. This giant is 9925 feet long and 130 feet high. It will so control the rise and fall of the river that three million acres of once dry and lifeless desert will soon be producing rich crops of cotton, corn, and beans.

CHAPTER XVII

THE STORY OF BACTERIA

THERE is a class of living organisms whose existence affects the life of the whole world, and yet which are too tiny to be seen with the naked eye. They are called 'microbes,' from the Greek *micros*, 'small,' the same word from which we get 'microscope' and 'microphone.' One class or subdivision of these invisible organisms is known as 'bacteria': they were so called by scientists who examined them under a microscope and noticed their rod-like form; in Greek the word for a rod is *bactron.*

The knowledge of bacteria has come in the last century, although two thousand years ago some one said, "It is to be noticed that if there be any marshy places, certain animals breed there which are invisible to the naked eye, and yet getting into the system through the mouth and nostrils cause serious disorders." But nobody then could prove this to be true, for these 'animals' could not be seen, and there were no microscopes in those days.

About 1675, Leeuwenhoek, the son of a Dutch lens-grinder, saw through one of his lenses minute, moving forms in a drop of stagnant water. Soon some of the

scientists began to study these *animalculæ*, 'little animals,' as they were at first called. They made drawings of what they saw, and these drawings are very much like those of the bacteria drawn by scientists to-day. Many people scoffed at the reports of the early scientists, paying no more attention to them than they would to "a tale told by an idiot." It was nearly two hundred years later that anything new was learned about bacteria.

Fifty years ago there could be seen at country fairs showmen who, for the sum of one penny, would allow a person to look through a small telescope at the spots on the sun, or, through a microscope, at the 'animals' wriggling about in a drop of water. People who looked at them thought they were as much a trick as sword-swallowing.

About seventy years ago Louis Pasteur, one of the most brilliant scientists of France, began to grow and cultivate these microbes, or dust plants, as they are sometimes called, because they appear to cling to dust particles in the air. Since then knowledge of them has increased, and they have been definitely classified by botanists as plants.

About twenty years afterward Robert Koch declared that he believed bacteria to be the cause of disease and not the effect, as many had thought them to be. This idea gave a great impetus to the science of bacteriology,

and made many men of science explore many new paths of knowledge, for the world to-day believes that no expense should be spared to preserve the health of mankind. No effort to save human life is thought to be too great.

One difficulty in studying bacteria has always lain in the fact that upon any particle of dust there may be found a dozen kinds of bacteria. The problem of the scientist is to separate the different kinds so as to study them one at a time. Koch used different substances on which to grow these tiny plants. Some thrive on potatoes, others grow in gelatine, and others in beef broth. In this way many kinds of bacteria have been discovered, those that produce tuberculosis, diphtheria, pneumonia, and typhoid fever being among the number.

Thus we see that only within the last fifty years has a knowledge of bacteria become of value to man, or, in other words, been reduced to a science. The science of bacteriology is of great value not only because bacteria have much to do with disease, but also because it is the foundation of our knowledge of sanitation, or the prevention of disease. This science promotes successful agriculture and the making of many products. Bacteria play their part in tanning hides, in curing tobacco, and in making butter, wine, and vinegar.

Let us consider some of the ways that bacteria assist mankind. A tree falls in the woods; an elephant or a bird dies in the jungle. Then and there millions of bacteria in the soil and air invade the dead bodies and change them into simple elements or gases, which spread out in the air or go back to enrich the soil. This process is called *decay*. Thus bacteria are of great assistance to man in helping to cause decay.

The tiny bacterial plants that live in the soil help to prepare food for the plants we cultivate. Some kinds of bacteria are harmful; but these soil bacteria are very necessary and helpful, and the farmer works hard to make the soil favourable to their growth. There are millions of bacteria in a cubic inch of fertile soil. They do not need sunlight as do most plants, but they do require air, moisture, warmth, and food.

Some kinds of bacteria set up housekeeping upon the tiny rootlets of certain plants such as clover, lucerne, beans, and peas. They take a certain element that we call *nitrogen* from the air, and store it up in little bunches or swellings on the roots of these plants, where it is ready for them to feed upon. Plants must have this nitrogen as food, and soil that contains an abundance of it is rich soil. Every farmer knows that the fields are richer where clover, lucerne, or peas have been growing. The reason is that millions of bacteria have been at work upon the roots, storing up nitrogen from the air

for them, and for other plants that follow them, to feed upon. In this way bacteria are very helpful to man in the growing of all nitrogenous plants.

Trees, grains, and grasses in order to grow must have certain simple foods, some of which are carbon, hydrogen, oxygen, and nitrogen. Plants absorb carbon from the air ; they get hydrogen and oxygen from water. There is plenty of nitrogen in the air, too, but plants cannot absorb it direct from the atmosphere. Bacteria, attaching themselves to the roots of clover, have the power of separating the nitrogen from the air and passing it on to the clover. Thus the clover grows, and when it decays it leaves much nitrogen in the soil.

Thus far we have been looking at the helpful kinds of bacteria. Let us now turn to the other side of the picture where we shall find the harmful ones. A knowledge of the bacteria of disease is important, for against these we must always be on guard. We cut a finger and allow the dust of the air to get into it, and it becomes inflamed. Some bacteria have entered the cut. To guard against this we should cleanse and bind up wounds in sterile gauze to protect them from air and dust.

The bacteria of decay must be defeated before food can be preserved. Most foods are subject to changes, to what is commonly called 'going bad.' Some become

sour, some bitter, some rancid, and some putrid. Food generally 'goes bad' because mould and mildew, which are cousins of the bacteria plants carried by the dust, have entered it and have begun to grow. We see colonies of these plants in mould which comes on the top of jelly glasses. If we buy food in tins which bulge out at the end we may find the contents spoiled; and if we do it is these little plants that are responsible. When clothes are covered with mildew, or when they begin to smell musty, it is these microbes of decay that have found a home in them. So it is when milk sours, when butter becomes rancid, when cider ferments, or when meat or eggs 'go bad.'

The natural place for all bacteria is the soil. When soil dries it may become dust and be carried about in the air with the bacteria. One might think that because of this the country would be a most unhealthful place. But this is not true. There is in the country air always more or less moisture to which these dust particles will cling and which will be carried to the ground; while in the dwelling-house in the city the air is usually dry so that the dust bodies fill the air. The old-fashioned dusting or sweeping stirs up the particles and forces them back into the air again. That is why the vacuum-cleaners and absorbent mops are used so much to-day instead of a broom.

Let us see how bacteria behave in milk. When milk

comes from the cow it has very few bacteria. But they are in the container in which it is placed. They fly from the clothing of the milker; they fall from the hide of the cow. Unless the udder of the cow has been washed, they fall with the particles of dirt into the pail. Straining will remove the larger particles of dirt, but the bacteria remain.

Since milk is a perfect food, all sorts of bacteria will thrive in it. They multiply rapidly until there are so many of them that the milk becomes sour. The more bacteria there are in the milk, the sooner it sours.

Bacteria multiply much more rapidly in warm food than in cold. So if we keep milk cool we reduce the number of bacteria and thus the milk stays sweet longer.

The modern method of preserving milk is by destroying the bacteria. The milk may be heated to the boiling-point; the heat kills all bacteria except the spores. Then if no others are allowed to get into the milk it will 'keep' for a long time. But most people do not like the taste of boiled or scalded milk. So the more usual method is to heat the milk to a temperature of from 140 to 160 degrees. This process is called *pasteurization*, after Pasteur, who was the 'father' of modern bacteriology. The pasteurizing heat kills the principal disease bacteria, but it does not kill all those

that cause milk to sour. The milk-bottle is then covered with a pasteboard cap, which prevents more bacteria from entering. Milk treated by this process will keep sweet much longer than milk which has not been so treated.

CHAPTER XVIII

JENNER, THE CONQUEROR OF SMALLPOX

EDWARD JENNER, the son of a Gloucestershire clergyman, was born in the year 1749. As a young man he was apprenticed to a surgeon in Sodbury, but after a time he went to London and studied under the celebrated John Hunter. Finally he returned to his native town of Berkeley, where he practised the arts of medicine and surgery till his death in 1823.

Everybody liked Dr Jenner. He was kind-hearted, cheerful, fond of music, fond of poetry, and keenly interested in his noble profession.

When Dr Jenner was studying at Sodbury a young countrywoman came to him for advice. While talking to her he chanced to speak of smallpox, that terrible disease which swept over the land every few years. The young woman said she could not catch smallpox because she had had cowpox. This was a new idea to Dr Jenner, but she declared it was true. She told him that everybody in her neighbourhood had proved this to be true. Every milker of cows, she said, who had ever caught a certain infection from the cow's udder was after that absolutely safe from smallpox. Dr Jenner asked other physicians about it, but they said

it was not a proven fact. Some said it was only a foolish notion of ignorant people. Jenner, however, thought it reasonable, and he began to investigate cowpox. He found that persons who had had cowpox were so certain they were safe from smallpox that they allowed him to expose them to that disease to prove it. They did not take it.

Jenner then conceived the idea of spreading cowpox, which is a harmless disease, in order to ward off the dangerous smallpox. He said, "If a man can catch the cowpox from a cow, why may not one person get it from another person?" He took the poisonous germs from the cow and planted them under the skin of his patients and gave them cowpox, after which they were immune from the dreadful smallpox.

Next he took the germs from a person who was ill with the cowpox and gave the milder disease to others. He had solved the problem of vaccination, which is merely spreading cowpox by inoculation in order to prevent smallpox. He proved it by testing a healthy boy aged eight. The lad was inoculated with cowpox from the hands of a milkmaid and contracted cowpox. Jenner then inoculated the boy with smallpox, and he did not take the disease.

Jenner was now certain of his ground. He therefore published his new discovery to the world. In the following year thirty-three physicians and forty

eminent surgeons signed a statement that they believed in the new discovery of Jenner. The King and Royal Family of England bestowed great attention upon him, and the new practice of vaccination began. Parliament voted him two grants of money, one of £10,000, and one of £20,000.

In six years news of the discovery had reached the most remote corners of all civilized lands, and the happy tidings were even made known among some of the savage nations. Soon smallpox ceased to be the most dreaded of all diseases.

Vaccination gave such relief from the fear of the dreaded scourge that clergymen in Geneva and Holland praised it from their pulpits. In some places there would be long lines of people waiting their turn to be vaccinated. Jenner's birthday was celebrated as a feast-day in Germany, and the first child vaccinated in Russia was named 'Vaccinov,' and was educated at public expense.

Honours were showered upon Jenner from the Old and the New World. On one occasion he requested Napoleon, who hated the English bitterly, to release a certain Englishman held a prisoner in France. The Emperor was about to refuse, when the name of Jenner was mentioned. "Oh," said Napoleon, "we can refuse nothing to *him*."

India has always been a land where smallpox raged.

During the Great War, when diseases threatened all nations, nine millions of people in India were vaccinated without a single resulting death. Other millions were vaccinated in the Philippine Islands, and there also smallpox disappeared.

Vaccination is now used to prevent other diseases, and the name of Jenner will always be held in grateful remembrance.

CHAPTER XIX

LOUIS PASTEUR DISCOVERS GERMS

Louis Pasteur's father used to come home at night from his hard day's work in the tanyard and take his little son on his knee and say: "Oh, Louis, if you could only become a professor in the college of Arbois, how happy I should be! Here I work all day with those evil-smelling skins, tanning them for leather. Many hard years I spent in camp as a soldier. I want you to have an easier life, my son. You must have education."

Louis was only two years old; so he played with his father's whiskers and laughed. And Louis' mother smiled and said, "Yes, our boy must have education." But in their most radiant dreams about the future of their son they had no vision of the great man he was to become.

If they could have looked forward sixty years they would have seen on the door of the very house where they were living a plate with gold letters, announcing:

Here was born Louis Pasteur
December 27, 1822.

The family soon moved to Arbois, where Louis' father had a tanyard of his own, and Louis played in

the yard and thought little of the future. When he went to school his father kept watch over his lessons, urging him to study every night. But in the daytime Louis liked to play. He sometimes ran away from school to go fishing. He was fond of drawing, and instead of studying he made pictures of his teachers and his classmates. The likenesses of these were very good, so good that had Louis lived to-day and attended a modern school his teachers would have urged him to study art. Perhaps with his talent, and the hard work which he afterward showed he was willing to do, he might have been a great artist instead of a great scientist. But then he was only thirteen and did not think much of his future, nor was he very industrious.

However, a few years later he began to realize how hard his father and mother were working in order to educate him, so he put away his fishing-rods and his drawing-pencils and began to study in earnest. As he forged ahead of the other students his teachers began to take note of him. They said: "He is a wonderful thinker. He will go far."

"You must think of the great University," said one of his teachers. "Some day you may teach there!"

Louis became greatly interested in chemistry. He asked his professor many questions that the poor man could not answer. Louis heard of an apothecary who had written some remarkable articles on chemistry, and

asked to be allowed to study with him on Saturdays. The lad performed many experiments of his own. He astonished his teachers by showing them how much phosphorus he had obtained from the bones of the meat he bought for his meals.

When he was ready to begin his studies at the University, and underwent the entrance examination, he stood fourteenth on the list. This did not satisfy him. So he studied hard another year, working in the meantime in order to support himself. This time he passed fourth on the list.

In the University he had two wonderful teachers. One was quiet and exact; the other was bubbling over with enthusiasm. With these men to encourage him Pasteur lived and breathed and dreamed chemistry. At twenty-five he had discovered some new laws and proved them to his teachers. One discovery was that two substances that chemists had always supposed to be different were one and the same. One of his professors made him come and perform the experiments in his own kitchen before being convinced.

Louis was now made an assistant professor of chemistry at Strassburg. So engrossed was he in his science, it is said that on his wedding-day a friend had to go to his laboratory to remind him that it was time for the ceremony.

Now he began to make some of the wonderful dis-

coveries that have saved thousands of lives all over the world. In the southern part of France the people made their living by breeding silkworms. Their homes were full of racks where they placed mulberry-leaves for the worms to eat. All at once the worms began to die. The malady grew worse. The eggs would not hatch, and when they did, the young worms would not eat, and there was a danger that there might be no more silk cocoons. The people sent to Spain and Italy for more worms, but in time these sickened and died. Every silk-producer feared he would lose his business. Finally, in 1865, the silkworm keepers sent a petition to the French Government praying for aid.

Some one said: "Louis Pasteur is the one to do it. He is not afraid to break new ground."

Pasteur came to Southern France. He examined the worms under his microscope and discovered small particles on their bodies. Then he took healthy worms and compared with them. He believed that these particles, or parasites, caused the disease from which the sick worms were suffering, but how did the healthy ones get it from those that were sick?

After many experiments he discovered that when a healthy worm ate a leaf over which a sick one had crawled it too got the disease. The silkworms have a little hook underneath their bodies. When a sick worm crawled over a sound one he found that the little

hook pricked the skin of the other and gave it the disease. He separated the well from the ill and destroyed the sick ones and all of their eggs. In time he controlled the disease and saved the silk industry of France.

In the meantime he had learned some wonderful truths that have been a great help in checking and curing other diseases. First of all, he had discovered that there are such things as disease microbes, which carry disease from one person to another.

By many successful experiments on animals he learned how to check disease in man. He practised with chickens that had cholera and with sheep sick with fever, and used his results in treating mankind.

Jenner had discovered that vaccination with the virus from cowpox would prevent smallpox, but Pasteur went much farther. He was fearless in his experimenting. He proved to his own satisfaction that if the skin was unbroken, contagious disease microbes could not enter the body, and in his laboratory he handled all forms of diseases. To him were sent animals and samples of blood of persons who had the most dangerous fevers. He inoculated white mice and rabbits and dogs and even cattle, first producing disease, then searching for a remedy.

Many dogs and rabbits lost their lives in the interest of science, but Pasteur was merciful. He used to say,

"I have never killed even a bird for sport; but when it is a question of saving human life I have no scruples about sacrificing animal life." However, when there was an operation that would cause suffering Pasteur always chloroformed the animal.

Some one tells of seeing him one day in his laboratory where a mad dog was tied to the table. The dog was foaming at the mouth, while Pasteur drew some of the poison saliva into a tube in order that he might find a cure for hydrophobia.

Some owners of cattle and sheep ridiculed Pasteur and challenged him to a trial. Pasteur accepted. Sixty sheep were put at his disposal. He vaccinated twenty-five of them against anthrax. Some days later these and twenty-five others were given the anthrax germs.

Pasteur then said that the second lot of twenty-five sheep would all die, while the first lot that had been vaccinated would live. It was arranged that believers and unbelievers should meet on 2nd June, 1881, at the farmyard where the sheep had been placed to celebrate a victory or to announce a failure.

When Pasteur arrived at the farmyard at two o'clock in the afternoon he was received with much applause. There were present many distinguished men, some of whom had ridiculed his teachings. Twenty-two of the unvaccinated sheep were dead and lying side by side.

Two others were breathing their last, while the remaining one was ill of anthrax. It died that night. All the vaccinated sheep were in perfect health. It was a wonderful proof and a great victory for Pasteur.

Shortly after he had completed his work in Southern France his left side became paralysed. He hastily codified all the knowledge concerning his discoveries so that some one else might go on with them. Though he was a cripple for the rest of his life, in two years he had regained his health to such an extent that he could continue his work.

Dr von Behring of the Pasteur laboratory found the antitoxin for diphtheria; he discovered and bottled up the germs that cause the disease. In the Pasteur Institute, by many experiments on guinea-pigs and birds and other animals, scientists found that by planting a weak microbe under the skin they could make the animal immune from the strong microbe. That is, by giving him the weak microbe they so changed his system that it could fight off the disease brought by strong microbes. In other words, Pasteur said he could fight poison or toxin with the same poison or toxin. To-day every doctor uses antitoxin for diphtheria. It is made from the blood of horses which have been made immune by giving them a little of the toxin at a time until they are proof against the poison.

Every new discovery in science has to fight for its

place in the world. Pasteur had many battles to prove to other chemists that he was right. Over and over again he performed his experiments to prove his new laws.

We have seen that the pasteurization of milk was discovered when Pasteur found that germs thrive better in some temperatures than in others. He taught the use of cold packs in reducing fever in typhoid. Upon the discovery of disease microbes is built the modern treatment of most illnesses.

CHAPTER XX

ANÆSTHETICS

THE term 'anæsthetic' comes from two Greek words, *an*, a negative, and *aisthesis*, 'feeling' or 'sensation.' 'Anæsthesia,' therefore, means the putting of a stop to feeling or sensation, and the 'anæsthetic' is the thing by means of which this is done. From very early times physicians had tried to hit upon some method of dulling pain, especially during surgical operations. Herodotus, the Greek traveller, tells us that the Scythians inhaled the vapour of a certain kind of hemp in order to produce a state of temporary stupor, and it is said that the Chinese of ancient times did the same. Pliny, the Roman naturalist, mentions that in his day the plant mandragora was given to patients about to undergo painful ordeals, so that they might become drowsy till the worst was over; and the power of opium to induce a heavy slumber was known many centuries ago. Still, nobody had discovered or invented an anæsthetic that would suspend consciousness entirely without putting the sufferer's life in danger until a little less than a hundred years since.

Two great English scientists of the early nineteenth century, Sir Humphry Davy and Michael Faraday,

had demonstrated that the inhalation of nitrous oxide and ether produced loss of sensation; but this idea was not followed up, or practically applied, for a long time. To an American dentist, Horace Wells of Boston, belongs the credit of having been the first to anæsthetize his patients with the aid of nitrous oxide gas. But another, and far more important discovery was at hand. Chloroform, that is to say, trichlormethane—the chemical formula is $CHCl_3$—had been used as an *internal* medicine for a number of years, but it was not until the third and fourth decades of the nineteenth century that researches were made into its effects when *inhaled.* In the month of March 1847 a Frenchman called Flourens read a paper before the French Académie des Sciences upon the reaction of the lower animals to chloroform vapour. Nobody seems to have been greatly interested in what he had to say; nobody seems to have grasped the tremendous importance of his experiments to suffering humanity. But before the year was out the attention of the scientific world was directed to the same subject by the work of Dr James Simpson, an Edinburgh physician.

James Simpson was the youngest of the seven sons of a village baker. At the age of four he began to attend the village school, and he showed such extraordinary quickness and eagerness in his first lessons that his father and his six elder brothers agreed to stint

themselves of all but the barest necessaries of life in order that he should be able to go to Edinburgh University. He entered the arts classes of the university in 1825, at the age of fourteen, "very, very young and very solitary" as he himself said forty years later, when the freedom of the city was conferred upon him. He graduated M.D. in 1832, after six years further study, and it was not long before his unusual ability was recognized, and he advanced to the very front rank of his profession.

In 1846 news reached Scotland of the experiments made by two Americans, William Morton and Charles Jackson, with sulphuric ether. Simpson was thrilled. " 'Tis a glorious thought," he wrote, "I can think of naught else!" He soon came to the conclusion, however, that a more efficient anæsthetic might be devised, and one, moreover, that did not necessitate a heavy and cumbersome apparatus. It was on 4th November, 1847, that Simpson and his two young assistants, Keith and Duncan, *inhaled* $CHCl_3$ for the first time. The result was rapid and startling. All three slid from their chairs on to the floor, under Simpson's dining-room table! A little while later the doctor's butler came in, but he felt no surprise and no alarm, as in those deep-drinking days it was quite a usual thing for gentlemen to collapse upon the carpet after the fifth or sixth bottle of port. He knelt by each unconscious

figure in turn, loosened the high stock-collar and the neckcloth, and took his departure' When, some time afterward, the three pioneers came to their senses they must have realized that a marvellous and—as Simpson himself would have put it—a *glorious* forward stride in science had been made that night.

A fortnight later Simpson gave a demonstration before his colleagues and students at the Edinburgh Royal Infirmary, and then began the amazing battle between the pioneers on one side and the narrow-minded, old-fashioned, obstructive people on the other. It seems almost impossible nowadays, but eighty years ago some of those people actually declared that the use of anæsthetics was contrary to the laws laid down in the Old Testament.

Of course the forces of progress won the day, though not without a hard struggle. Simpson was made a baronet, a Royal Physician, and a Doctor of Civil Law of Oxford University. He will be remembered with honour and with thankfulness for ever, he through whom "one of God's best gifts to His suffering children"[1] became known.

[1] *Rab and his Friends*, by Dr John Brown.

CHAPTER XXI

THE FIGHT AGAINST TROPICAL DISEASE

In the ancient myths and legends of the human race heroes are often seen fighting against enormous giants, and knights against huge dragons. No doubt a giant could do a great deal of damage, especially when he was in a bad temper, and a dragon was capable of devouring a very large number of people during its lifetime; and certainly the story of the conquest of these creatures by valour and wisdom is full of romantic colour. But a thousand times more romantic is the true story of how one man in our own days overcame a tiny but terrible enemy which had slain—and but for him would continue to slay—not thousands but *millions* of human beings every year.

That man is Sir Ronald Ross, and the enemy he has overcome is the malaria-carrying mosquito.

A very striking point of difference between Sir Ronald and all the giant-quelling and dragon-slaying heroes of mythology is this: that *they* all knew quite well beforehand *what* was the monster they had to vanquish, and *where* it was to be found, whereas *he* had first to discover in what *form* the enemy power was contained, and *where* it could be met and tackled. The

quest occupied many years of hard and patient work: it was crowned with triumph on 16th August, 1897, when Ross discovered the parasite of malaria in the stomach of a female *Anopheles* mosquito.

For the terrible force which he had set out to find and overcome was *malaria*, that far-stretching, dangerous, destroying, and devastating disease which is responsible for one-third of the total hospital attendances in tropical countries, and which "during the past ages has caused ravages among mankind to the extent of uncountable millions of deaths." It has been more deadly in warfare than shot or shell, and so fatal to health and industry in peace that "there are very few people who do not, either directly or indirectly, pay for the trail of sickness left by the mosquito throughout the tropical and sub-tropical world." Many historians believe that this evil insect was the cause of the downfall and decay of "the glory that was Greece," and that malaria, and not a gradually diminishing moral energy, brought to nought the most highly intellectual nation in the history of mankind.

Not until Ross's great discovery—"the greatest thing done in our time by one man," says John Masefield the poet—did anyone succeed in proving that the mosquito was the carrier of the deadly infection. People *had* noticed that the disease was most prevalent in marshy places, but they concluded that the source

of the mischief was the *bad air*—hence its Italian name *malaria*, the name by which it is generally known.

In 1878 Dr Laveran, a French army surgeon, discovered the malarial parasite in human blood ; sixteen years later a Scottish scientist, Sir Patrick Manson, suggested that the mosquito might convey the poison from an infected to a healthy person. But there is a very long stride from theory to proof, and years passed, and millions of people died of malaria, and millions more were permanently invalided by it, and humanity seemed as far as ever from deliverance from this scourge.

Then Ronald Ross, another Scot, at that time an officer in the Indian Medical Service, set his lance in rest against this invisible enemy. The story of his toils, his disappointments, his indomitable faith and courage, is one of the most thrilling in the history of the British race. There was only one course possible—to keep on dissecting mosquitoes under the microscope until at last the malarial parasite was detected. The task demanded the strength of ten giants and the patience of as many Jobs. Ross had to work in tropical heat, without the cool breeze of the punka, which would have scattered the fragments of mosquitoes on his table; he had to spend about two hours over *every* insect, while its living relations assailed him without truce; and the natives, who were destined to benefit more than any

other people in the world from his discoveries, looked askance at him, suspected him of witchcraft, and were reluctant to have their fingers pricked and their blood tested, even though they were offered what would seem to them the lordly sum of three rupees for each prick!

At last, on that memorable 21st of August, nearly thirty years ago, the warrior caught a glimpse of the Thing he had set out to slay. On that day Ronald Ross saw, and seized, upon the wall of his room a mosquito of a different type from any that he had examined. It belonged to the family very appropriately called *Anopheles*, which in Greek means 'harmful'; and later in the same day one of his collectors brought him in a bottle which contained about a dozen of the same kind. One by one the insects were placed under the microscope and dissected, micron by micron—a micron is the one-thousandth part of a millimetre—but there was nothing new, nothing remarkable in any one of them until the very *last* was reached. Here we must let the discoverer relate the thrilling close of his pursuit in his own words:

> The dissection was excellent, and I went carefully through the tissues, now so familiar to me, searching every micron with the same passion and care as one would search some vast ruined palace for a little hidden treasure. Nothing. No, these new mosquitoes also were going to be a failure: there was something wrong

with the theory. But the stomach tissue still remained to be examined—lying there, empty and flaccid, before me on the glass slide, a great white expanse of cells like a large courtyard of flagstones, each one of which must be scrutinized—half an hour's labour at least. I was tired, and what was the use? I must have examined the stomachs of a thousand mosquitoes by this time. But the Angel of Fate fortunately laid his hand on my head; and I saw a clear and almost perfectly circular outline before me of about twelve microns in diameter. The outline was much too sharp, the cell too small to be an ordinary stomach-cell of a mosquito. I looked a little farther. Here was another, and another exactly similar cell. The afternoon was hot and overcast; and I remember opening the diaphragm of the sub-stage condenser of the microscope to admit more light and then changing the focus. *In each of these cells there was a cluster of small granules, black as jet. . . .*

These were the malarial cells. A day later it was seen that they had increased in size. And then, stage by stage, the career of the malarial parasite was traced from the stomach of the Anopheles to its proboscis, whence it is injected into the blood-stream of the insect's victims. This discovery was glorious and memorable, not only because it led the way to prevention and successful treatment of malaria, but because it enabled doctors and scientists to tackle other tropical and non-tropical diseases by following the same line of attack. On 15th July, 1926, the Prince of Wales

performed the opening ceremony of the Ronald Ross Institute on Putney Hill, where people suffering from tropical diseases receive treatment, and enthusiastic scientists, under the direction of Sir Ronald himself and the well-known Italian bacteriologist, Dr Aldo Castellani, are pursuing many different branches of research in connexion with many painful and deadly diseases, among them the deadliest of all—cancer.

The good work which this Institute is doing—and will continue to do—for the relief of suffering and the advancement of science cannot be measured—or even expressed—in words. "From this building," said the Prince of Wales, "may issue results which will bring back health to thousands who have lost it, or safeguard the lives of countless others threatened by unseen dangers in tropical lands. More than that, it may open out, for the use and benefit of mankind as a whole, huge districts which are at present denied to civilization."

No really great discovery is self-contained, the be-all and the end-all of any particular branch of knowledge. From this lamp first lit by Ronald Ross a hundred others have been kindled. It was owing to his detection of the malarial parasite in the Anopheline mosquito, and the experiments and researches which followed, that the American scientist, William Crawford Gorgas, was able to stamp out yellow fever from the territories on either

side of the Panama Canal, thereby making possible the completion of this great engineering feat, which had been retarded and almost frustrated by the constant ill-health of the engineers and navvies engaged upon its construction.

Dwellers in tropical countries are exposed to many distressful diseases from which the fortunate people in temperate zones are free, and most of which are caused by some parasitical organism. Until the character and source of the guilty organism are known nothing can be done to check the devastations of the disease. That is why the discoveries made by Dr Aldo Castellani are of such tremendous importance. Like many other Italians who have won great victories in the fields of the intellect, Castellani is a Florentine by birth. He spent twelve years in Ceylon investigating tropical diseases, and, besides identifying several previously unknown causative organisms, discovered the germ responsible for one of the most common and painful of tropical maladies, the skin disease called 'yaws.' During the war his services were lent to Britain by Italy, in whose Army Medical Service he held the rank of Lieutenant-Colonel, and he served for a time in the Balkans, where opportunities of studying many types of disease at close quarters were as numerous as even the most enthusiastic of scientists could desire. But perhaps the most memorable of all Castellani's discoveries—up to the

present—was made when as a very young man he was sent out to Uganda as a member of the Royal Society's Commission on Sleeping Sickness. (This illness must not be confounded with sleepy sickness, *encephalitis lethargica*, which is quite different.) In the cerebro-spinal fluid of patients suffering from this disease he found a protozoan parasite to which has been given the name of *Trypanosoma* (from two Greek words, *trypanon*, 'a borer,' *soma*, 'a body'), and which he soon demonstrated to be the source of the evil. The Trypanosoma may exist in the blood of wild animals, such as the antelope, or in domesticated animals, such as the dog. The 'carrier' in this case is not the mosquito, but the two-winged, brown and yellow *tsetse*-fly.

Every victory won by science is a victory of light over darkness, and there is none that can be limited by time or place. The desert and the wilderness, the jungle and the swamp, that were once sinister and poisonous, the haunts of death in many subtle and horrible forms, will some day be pure, fair, and safe, thanks to the great gifts which men of science have used—and are still using—with magnificent forgetfulness of self, in the service, and for the sake, of all mankind.

CHAPTER XXII

THE CONQUEST OF YELLOW FEVER

We have seen how, one by one, the causative organisms of tropical diseases were discovered, and how the genius and perseverance of a Scot, an Italian, and an American overcame these invisible foes of humanity. The microbe which produces yellow fever was first detected by a Japanese.

Other scientists had been able to identify the mosquito which carried the fever—the stegomyia—but nobody had discovered the microbe itself. They had hunted it, using methods that had been successful in detecting other disease germs, but in vain. These yellow-fever germs were known to be very small because they passed easily through porcelain filters, the pores of which were so minute that most microbes were held back. It seemed possible that they might be *so* minute as to be entirely beyond the power of a microscope. The disease had been controlled by constant watching, but the last step to complete success was to find the germ. It was tantalizing, indeed, and the scientists would not give up the challenge.

In the summer of 1918 the city of Guayaquil, Ecuador, was suffering from a severe epidemic of yellow

fever. Lord Bryce had said that this city was the pest-house of South America and the last stronghold of this deadly peril, except the banks of the Amazon. When the people of Guayaquil asked the Rockefeller Institute for Medical Research of New York to send them some experts, the best were chosen to aid in the fight, and among them was the eminent Japanese student of bacteria, Dr Hideyo Noguchi. Dr Noguchi was educated in the schools of Japan and in the Tokio Medical College, and had for nearly twenty years been on the staff of the Institute. He had long been a successful hunter of small disease germs and knew well how to grow them in a kind of food jelly, and how to experiment with them. Thus he had discovered many germ secrets. Moreover, Dr Noguchi was well acquainted with a disease called 'infectious jaundice,' which is much like yellow fever. He had discovered the germ of jaundice in Japan by careful tests and hard work.

The yellow-fever mosquito breeds in fresh-water containers about and in the homes of men. It is rarely found in pools of water on the surface of the ground, and never in the fields and swamps. It is a domestic mosquito, clinging to buildings that are inhabited and avoiding direct sunlight.

The female lays between one hundred and one hundred and fifty eggs at a time. These eggs are

deposited on the surface of the water—always in a barrel, tank, tin can, flower vase, broken bottle, or the like. From each egg there comes a wriggler, or larva, which after several changes or moults becomes a mosquito. If it be a female it starts at once to find a victim from whom to suck blood. Should this victim be ill with yellow fever in the early stages, the mosquito will absorb the germs from the blood. After about twelve days the mosquito has fed the germs till they are able to give yellow fever to the victim she bites.

In Guayaquil there was no modern system of water distribution. The water was delivered to the houses at certain hours each day. Thus the water had to be stored so as to last till the next day.

In the better-class homes it was stored high up on the walls in tanks provided with valves for letting the water out. There were about seven thousand tanks in use in the city. In the humbler homes the people used barrels, oil tins, large bowls, and all sorts of containers. Of these there were thirty thousand or more.

The American experts at first thought that the best way to check the disease would be to do away with these water-containers. Before this could be done, however, it would be necessary to instal a modern water system in the city, so that an abundance of water could be carried to the people at every hour of the day. But this would require two years, and in the meantime

yellow fever would be killing hundreds. A modern water system has since been built, but the scientists could not wait.

They next thought of screening the water vessels, but there were too many of them. Besides, the necessary wire screening was scarce, and it would have taken months to import supplies.

Then they thought they could strain the water through muslin and thus separate the mosquito eggs and larvæ. This was not a 'cheering idea' because it would require a great amount of time and care. They at last set out to find a fish that could be put into all these thousands of receptacles to devour the eggs and larvæ. Fish had been used for this purpose before in places infested by yellow fever.

The first fish tried was a small one called a *top minnow*. It would eat mosquito eggs in streams, but in barrels and other containers it found so much other food in the water that it could not be relied upon to devour all the eggs and larvæ. Besides, it is not a hardy fish, and a slight shock produced by dipping a pail into the water will kill it. For these reasons the experts decided to search for another fish better suited to their purpose.

The next fish to be experimented with was a kind of perch called *huijas*. This fish is a voracious eater of mosquito eggs, and it can be roughly handled in long

trips in pails and cans. The scientists were now sure that their problem was solved. But it was soon discovered that this little perch was so unhappy in the small tanks and barrels that it would jump three or four feet out of the water in its endeavours to escape.

The experts then tried a little sardine which seemed just the fish to do the work. It spends most of its time on the surface just where the mosquito eggs are floating, but when any noise is heard it quickly swims to the bottom and remains there until all is quiet again. However, this fish was not plentiful, and it would have cost too much to furnish it for all the water tanks in the thousands of homes.

Finally, a little fish called the *chalaco* was tried and adopted as the most satisfactory for consuming mosquito larvæ and eggs in small, dark tanks. *Chalaco* are so plentiful in Ecuador that the cost was only a farthing apiece. Fishermen caught them by the hundreds from the streams, and put them in wells containing the same water in which they had been living. After a few days the fish were removed to another well containing city water, with no food except what they could get in the water. Soon they were carried in pails to the homes and put in the thirty thousand water vessels where they were happy and busy. Some of the very same fish were living two years later. So active and hungry were these little fishes that they devoured nearly all the

mosquito eggs and larvæ in the water-cans of Guayaquil, and that city has since been almost entirely free from yellow fever.

However, Dr Noguchi was not satisfied until he found the germ itself. He experimented on guinea-pigs, dogs, and monkeys with the deadly mosquito, and after long and careful work he found the germ in the blood of these animals. With the blood he transmitted yellow-fever germs to guinea-pigs, and made a thorough study of the development of the disease and the time it takes to infect animals. He took the germs from one animal and through them gave the disease to other animals.

The germ of yellow fever is a very tiny, slim spiral. It went wriggling and twisting about in the blood or in the culture food in which Dr Noguchi raised it. It is so small that even the best microscope will not always show it. The yellow-fever germ proved to be not a bacterium, which belongs to the vegetable world, but a protozoan, or a lowly parasite that is not quite an animal and not quite a plant.

No sooner had Dr Noguchi discovered the germ than he set out to make a vaccine that would prevent the disease in men, even when they had been bitten by an infected mosquito. He first killed some of the germs and inserted them under the skin of a guinea-pig to see if he could make it immune. Then he tried

to give it the disease by inserting live germs in its blood, and to his great joy the animal had become immune, and remained so for six months. Larger doses prolonged this time. Thus had Dr Noguchi learned how to vaccinate against yellow fever. He vaccinated some soldiers who were to be sent into an infected region, and though several of them had the fever he found he was on the right track.

Ten thousand people in a yellow-fever district were vaccinated in 1921, and not one who received two injections took the disease. It requires fifteen days for the vaccine to become effective.

In 1921 a very severe epidemic swept into Peru, where fifteen thousand cases were reported. This plague could not be stopped by vaccination, for the native population were obstructive and would not permit it. However, by a campaign against the mosquitoes the disease was conquered.

In another case six hundred soldiers who were to be sent into a district where there was a severe yellow-fever epidemic were vaccinated beforehand, and not one took the disease. Another great scientist had won another wonderful victory over a hidden enemy of man.

Dr Noguchi also made a serum to be used on persons already ill with yellow fever. Of one hundred and seven cases treated with the serum before the third day only fourteen died.

CHAPTER XXIII

RADIUM THE MAGIC METAL

RADIUM is a white powder that looks like table salt. A pound of it would be worth a thousand pounds of gold. Radium is very costly because it is so scarce. A mere pinch of it is worth a small fortune. There are only a few spoonfuls in all the world.

But radium is so powerful that too much of it would be dangerous. If a pound or two could be gathered at one spot it would kill people who came near. You might approach and even handle the powder without feeling any pain, but in a week or two your skin would peel off, your eyes would become blind, and death would soon follow.

Even the tiny quantities that we possess have caused harm to those who have experimented with them. One man carried in his waistcoat pocket a small tube of it to use in a lecture, and about three weeks afterward the skin under the pocket turned red and began to fall away: a deep and painful sore formed that took weeks to heal. Radium is so scarce, so costly, and so powerful that only men of science dare experiment with it.

When seen in the dark radium glows like living fire. The marvel of it is that while it gives off light and heat

continuously, it does not seem to lose any weight. Think of a piece of coal burning day and night for many years, always giving off light and heat but losing no weight that you could measure, and not turning to ashes. A pound of radium will melt a pound of ice every hour, and continue to do so almost indefinitely. That is much like the 'perpetual motion' that men have longed to discover for centuries. If you could put enough radium in a furnace you would never again have to feed or clean it.

A certain scientist kept his radium tubes in a pasteboard box for a time. When the box was broken he removed the tubes and threw the box aside. Several days later, having occasion one night to turn off the lights in his laboratory, he found the discarded box glowing in the dark. It had absorbed some of the rays of the radium. Nearly every object that comes in contact with radium becomes 'radio-active.'

This means that other substances get some new power from the radium, especially the power to shine or glow in the dark. Wherever darkness is a cause of danger radium may be used to point the way to safety. A kind of radium paint is used on power-line switches where a fumble might cause electrocution. It is also used on watch and clock dials, on labels for poison bottles, on keyholes, and on the eyes of children's dolls.

You may wonder how radium, which is so costly, can be used on a half-guinea watch-dial. The secret is that it is not the radium that is glowing, but the zinc sulphate that has only a tiny trace of radium. A mere pinch as big as a pin head will make the zinc shine on hundreds of thousands of watches.

If you should examine such a dial through a powerful magnifying-glass you would see the tiny explosions of the atoms of radium. These atoms explode at the rate of two hundred thousand a second. Thus the radium bombards the zinc till it glows. While the radium will last almost for ever, the zinc wears out after being bombarded for a few years. The better the zinc the longer it will glow.

It is as a cure for disease that radium is most helpful to man. It is used to treat thousands of cases of cancer each year. Many cases are cured, and in others the suffering is relieved. It is also used as a cure for tumours. In nearly every large city there is a hospital that is supplied with a small amount of radium. The surgeon uses only a tiny bit, perhaps the size of a pin head, but even that may cost many hundreds of pounds.

How radium was discovered is a fascinating story. In 1896 M. Becquerel, a Frenchman, was making some experiments with certain things that shine or glow without seeming to be hot. They are said to be phosphorescent. Becquerel exposed a metal called

pitchblende, an impure uranium oxide, to the sunlight until it became phosphorescent, and he then tried its effect on a photographic plate. It was a rainy day, so he put the plate away for several days in a drawer. When he developed the plate he was surprised to find on it a better image than sunlight would have made. Thus, by a sort of accident, he discovered that pitchblende will yield a substance, *uranium*, that is radio-active.

Two years later Professor Curie and Madame Curie, of Paris, found that some of the pitchblende with which they were experimenting was much more powerful than any uranium that they had used. They began to wonder if there was something in pitchblende more powerful than uranium.

Madame Curie was born in Poland and educated in Warsaw. She chose science as her field of study and went to Paris to complete her training. There she married the French scientist, M. Pierre Curie, and together they began to study radio-active bodies. Finding that some pitchblendes were much more radio-active than uranium, they wisely concluded that there must be some other substance in the pitchblende besides uranium, and Madame Curie set to work to find it and separate it from the other elements. The Curies kept 'boiling down' the waste rock left at the uranium mines until they found a strange, new element

something like uranium, but different, which Madame Curie called *polonium*, after her native land, Poland.

The Curies did some more 'boiling down,' and finally obtained the entirely new substance 'radium,' which is the most radio-active of anything we know about.

To obtain radium is a very difficult and expensive process. In the first place pitchblende, from which we first got radium, is not plentiful. It is found in Norway, Egypt, North Carolina, Colorado, and Utah. It is also obtained in small lumps in veins of gold, silver, and mica. From pitchblende it is easy to get uranium. But to get radium from the refuse left over is a difficult task. Professor Curie says you would have to refine about five thousand tons in order to get about two pounds of radium. Some one has said there is more gold in sea-water than radium in the earth.

In order to obtain one thimbleful of radium the machinery must reduce a trainload of ore. It must go through five thousand different stages which take six months to complete.

Experiments have been made to find out the effect of radium on mice, guinea-pigs, and other animals. If they are exposed to the light of radium long enough, they all lose their fur, then become blind, and finally die.

The great thing about radium, besides its tremendous power, is that every ounce that is added to what we already have is pure gain, for the metal will last almost

for ever. It will continue to give off light and heat for sixteen hundred years, and even then it will be one-half as powerful as at the start. After a second period of sixteen hundred years we should still have a quarter of the amount we started with. It will go on like this for twenty thousand years, when it will at last change into common lead.

Scientists believe that this mysterious metal will be a key to the unknown in science. Through radium they hope to learn how to change one element into another. It would be interesting and profitable to change metals into gold. But it would be worth more to man to learn how to get all the power from the atoms to do man's work. If we can only unlock this secret of nature we shall have a new world.

The investigation of the properties of radium has led to wonderful discoveries about the nature of the atom—discoveries which prove that each individual atom is, as it were, a solar system, rotating round a 'pole' or nucleus, and possessed of indestructible vitality. Thence we have learnt that in the realm of natural law there is no such thing as *death*, but only infinite capacities for *change*. It is by following this line of research that scientists hope to unlock many of the still-baffling secrets, not only of this world, but of the universe.

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